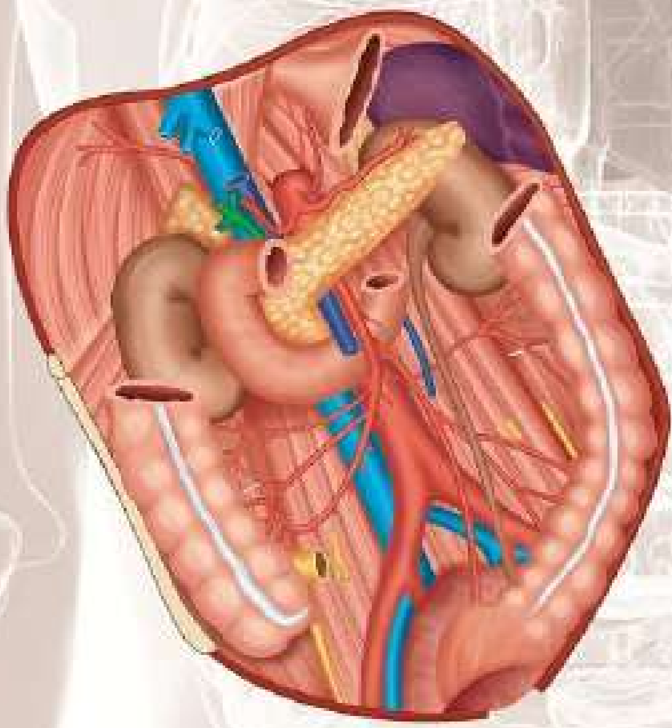
Inderbir Singh's ***Textbook of***

ANATOMY



Volume Two

Thorax

Abdomen and Pelvis

6th Edition

Edited by

Sudha Seshayyan

Volume II

Inderbir Singh's

TEXTBOOK OF ANATOMY

Sixth Edition

VOLUME I

VOLUME II

VOLUME III

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ANATOMY

Sixth Edition

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Late Professor Inderbir Singh
(1930–2014)

Tribute to a Legend

Professor Inderbir Singh, a legendary anatomist, is renowned for being a pillar in the education of generations of medical graduates across the globe. He was one of the greatest teachers of his times. He was a passionate writer who poured his soul into his work. His eagle's eye for details and meticulous way of writing made his books immensely popular amongst students. He managed to become enmeshed in millions of hearts in his lifetime. He was conferred the title of Professor Emeritus by Maharishi Dayanand University, Rohtak.

On 12th May, 2014, he was awarded posthumously with* Emeritus Teacher Award *by* National Board of Examination *for making invaluable contribution in teaching of Anatomy. This award is given to honour legends who have made tremendous contribution in the field of medical graduate. He was a visionary for his times, and the legacies he left behind are his various textbooks on *Gross Anatomy*, *Histology*, *Neuroanatomy* and *Embryology*. Although his mortal frame is not present amongst us, his genius will live on forever.

Preface

Castles of all medical wisdom are anchored to the knowledge of anatomy. Both the learning and the teaching of anatomy have undergone masterly changes. Though the limits of human anatomy appear to be confined to the boundaries of the human body, newer frontiers have constantly appeared due to two primary factors—one, expanding basic medical and clinical research and two, larger understanding of hitherto unexplained areas.

The preparation of a textbook on Anatomy should have the scope to adequately accommodate the growing changes. At the same time, it also cannot become disproportionately large, considering the time span within which an average undergraduate medical student would have to acquire this knowledge.

This edition of Inderbir Singh's *Textbook of Anatomy* has been prepared keeping the twin factors of the restructuring of medical curriculum and the knowledge expansion in mind. Many of the chapters have been completely revised and rewritten. Clinical Correlation has been clearly laid out. Embryological and Histological details have been added so as to give the reader a comprehensive picture. Newer features like Multiple Choice Questions and Clinical Problem-solving have been appended to each chapter in order to provide the reader with the opportunity of self-assessment.

A student entering the medical curriculum is faced with a completely new atmosphere. In an attempt to familiarize the student not only with Anatomy but also with the nuances of the medical world, new sections on *General Anatomy* and *Genetics* have been added. Professor Inderbir Singh's eye for details and meticulous writing style have always been popular amongst generations of medical students. Though many areas of the book have been revisited, the basic spirit and nature of the book have been retained. Additional features like *Added Information* and *Clinical Correlation* in any chapter will be of much help not only to the undergraduate students but also to the postgraduates.

At this juncture, I would like to place on record my appreciation and gratitude to Dr Hannah Sugirthabai Rajila Rajendran, Professor, Department of Anatomy, Chettinad Hospital and Research Institute, Kanchipuram District, Tamil Nadu, India; Dr M Nirmaladevi, Associate Professor, PSGIMS & R, Coimbatore, Tamil Nadu, India and Dr J Sreevidya, Assistant Professor-cum-Civil Surgeon, Madras Medical College, Chennai, Tamil Nadu, India for their painstaking editorial assistance. I would like to thank Dr Indumathi. S, Professor and HOD, Department of Anatomy, Chettinad Hospital and Research Institute, Dr T Anitha, Dr Elamathi Bose and Dr Bhuvaneswari, Assistant Professors of Anatomy, Madras Medical College, Chennai for their help during the preparation and review of the manuscripts and formulation of chapters.

I would be failing in my duty if I do not acknowledge the contributions of Dr Lakshmi, Dr Kanagavalli, Dr Arrchana, Assistant Professors, Department of Anatomy, Madras Medical College, Chennai and Dr Dharani, Assistant Professor, Villupuram Government Medical College, Villupuram, Tamil Nadu, India towards the completion of this edition. Shri RAC Mathews, Shri Ranganathan and Shri Sashikumar were instrumental in providing the necessary assistance, and Shri E Senthilkumar provided some of the illustrations for the book and I would like to extend my thanks to each of them.

Special thanks to Shri Jitendar P Vij (Group Chairman) and Mr Ankit Vij (Group President), Jaypee Brothers Medical Publishers (P) Ltd., without whom this edition would not have seen the light of the day. I am extremely thankful to them for reposing their confidence in me and providing the opportunity to revise Inderbir Singh's *Textbook of Anatomy*. Dr Sakshi Arora (Director, Content and Strategy) has been the driving force behind all efforts and deserves a very special thanks. She has provided insights and innovative ideas which have gone a long way in consolidating this book to best meet the needs of the taught and the teacher alike. We are thankful to her entire Development and Content Strategy team consisting of Ms Nitasha Arora (Project Manager), Mr Bunty Kashyap, Mr Phool Kumar, Mr Puneet Kumar Das, Mr Vikas Kumar, Mr Neeraj Choudhary, Mr Sanjeev Kumar and Mr Sandeep Kumar (Designers and Operators), and Ms Ankita Singh, Ms Sonal Jain, Ms Neelam Kakariya, Mr Prashant Soni (Editorial) for their constant technical support throughout the project.

This book is the combined effort of a number of people who have contributed in myriad ways and it may not be humanly possible to list down the many; however, I take this opportunity to extend my thanks to all of them.

Sudha Seshayyan

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Section 4

Thorax

Chapter 1

Overview of Thorax

Frequently Asked Questions

- Write notes on: (a) Thoracic outlet, (b) Thoracic cage.
- Give a brief account of the thoracic cage and its importance.
- Enumerate three of the landmark lines of thorax and trace their levels of occurrence.

INTRODUCTION

Thorax (Greek.thoresso=chest) is the region between the neck and the abdomen. The thorax has a large cavity, called the ***thoracic cavity***, contained within its walls; within this cavity, it contains important viscera like the heart and the lungs. The structures passing from the neck to the abdomen also traverse through the thorax.

The bones of the thorax form the thoracic cage or the bony thorax. Twelve thoracic vertebrae, twelve pairs of ribs (including costal cartilages) and sternum together form the thoracic cage.

The thorax has a superior aperture that connects it to the neck and an inferior aperture that connects it to the abdomen. The superior aperture is formed by the body of the first thoracic vertebra posteriorly, the first rib and costal cartilage on each side and the upper part of the manubrium sterni anteriorly. It is kidney shaped; the anteroposterior diameter is 5 to 6 cm and the side to side diameter is 10 to 13 cm. The inferior aperture is formed by the body of the twelfth vertebra posteriorly, the twelfth rib and the lower six costal cartilages on each side and the ***xiphoid process*** anteriorly. Due to the obliquity of the ribs, the joining of some of the lower costal cartilages to each other and the presence of floating ribs, the shape of the aperture is ill-defined.

The cavity of the thorax is also kidney shaped on transverse section. The vertebral bodies appear to be pushed forward into the cavity. The ribs, starting from the vertebrae, are initially carried backward and then bend to run forward. All these factors compress the anteroposterior diameter of the thoracic cavity. The anteroposterior diameter is the least in the median sagittal plane and is the greatest in the lateral sagittal plane.

Anteroposterior flattening of the thorax, backward curving of the ribs and dorsal placement of scapulae are anatomical features, which are associated with the erect posture of humans and have functional significance. The most important of these is the backward curving of the ribs. The projecting spines of the vertebral column are thus submerged into an osseo-musculo-ligamentous gutter and the back attains a flatter surface. Hence, a human can comfortably lie on the back, while a quadruped (examples like a dog or a cow) cannot.

The two terms 'thorax' and 'chest' are not synonymous and equivalent. The 'chest' is more a term to indicate the upper part of the trunk in a general outlook. This part of the trunk is broadest superiorly, with the side to side diameter being measured from shoulder to shoulder. Chest includes the pectoral girdle and the pectoral and scapular musculature, which anatomically belong to the upper limb.

The 'thorax' is a domed cage (shape of a bird cage with a dome) and is narrowest superiorly. The circumference increases inferiorly and the maximum circumference and size of the thoracic cage is reached at the junction of it with the abdominal part of the trunk. However, external appearance gives an exaggerated picture. The inferior thoracic wall (or the floor of the thoracic cavity) formed by the diaphragm is deeply invaginated into the thoracic cavity. It is pushed upward by the abdominal viscera. As a result, the lower part of the thoracic wall surrounds the abdominal cavity and abdominal viscera.

The thorax is an extremely dynamic region of the body. The walls and components are constantly in motion. Most of the inner structures like the heart, great vessels, lungs, trachea and oesophagus are also moving. The joints and bony components of the thoracic cage are flexible; this flexibility allows the thorax to withstand external blows and pressure, and to change its shape, and size as required by the demands of respiration and circulation. However, the 'domed cage' shape of the thorax gives rigidity despite the bony components being light in weight. The cage performs following function:

- Protects the internal organs from external forces;
- Resists the negative internal pressures generated during respiratory movements;
- Provides for attachment and support of the upper limbs;
- Provides for attachments of muscles and support to various body regions like the neck, abdomen and back; and
- Aerates the blood circulating in the lungs by expanding and contracting like bellows.

The thoracic cavity has three primary compartments. These are the ***central mediastinum (regio mediastinale)***, and the ***right and left pulmonary cavities (regiones cavitates pulmonale)***. The most important content of the mediastinum is the ***heart***; the pulmonary cavities contain the lungs.

Added Information

- ***Thoracic outlet:*** The superior aperture of the thorax had been called the ***thoracic inlet*** in olden times. It was so called, because the aperture appears to be the passage into the thoracic cavity. However, it has been noted that through this passage emerge important vessels and nerves from within the thoracic cavity to reach the neck and upper limbs. Hence, the term has been modified and the aperture is called the ***'thoracic outlet'***. It is the opening through which the thorax communicates with the root of neck. The opening is obliquely placed and faces upward and forward.
- The larger opening through which the thorax communicates with the abdomen is the inferior aperture. Though the oesophagus and several large vessels pass through this aperture, it is not called so because it is closed by the diaphragm and all the passing structures pierce the latter.

Clinical Correlation

Thoracic outlet syndrome: The brachial plexus of nerves and the subclavian vessels are closely packed at the level of the thoracic outlet as they enter the upper limbs. Due to restricted space and the obliquity of the aperture, the nerves and vessels may be compressed causing pain and other related symptoms. Nerve compression may lead to muscular wasting and vascular compression may compromise blood supply to the upper limb. The condition is called ***thoracic outlet syndrome*** since the various structures present in the thoracic outlet are responsible for the compression.

Dissection

Attempt to look at the thoracic cage and its movements in a live individual.

In the dissection theatre, study the undissected thoracic area. Try to palpate the ribs and the intercostal spaces. Palpate the jugular notch and the sternal angle.

THORACIC WALL AND CAVITY

The thorax is part of the human trunk which encloses the body cavity called the ***coelom***. The coelomic cavity of the trunk is subdivided into that part which is within the thorax and the other within the abdomen. The thoracic part of the coelomic cavity is the ***thoracic cavity*** and the one within the abdomen is the abdominal cavity. There are several organs and structures occupying parts of these cavities. To give protection to the internal structures and to keep the body contour intact, the walls of thorax and abdomen (without being mere flaps of skin) have bones, muscles, connective tissue, vessels and nerves.

The ***thoracic wall*** includes the thoracic cage (bone) and muscles which extend between the ribs (muscles). The skin, fascia and muscles covering the anterior and lateral aspects of the thoracic cage are also parts of thorax. The skin, fascia and muscles covering the posterior aspects of the thoracic cage are not customarily included in thorax but are considered parts of the 'back'. On the anterior aspect too, the pectoral region and the mammary gland, though topographically related to the chest wall, are functionally related to the upper limb.

The thoracic cavity is subdivided into three parts: a ***central mediastinum*** and the ***right and left pleural cavities***. The mediastinum contains the heart and organs related to transport of blood, air and food. The pleural cavities are cavities, which house the lungs.

The thoracic wall is supplied by the intercostal nerves. The arterial supply is by the posterior intercostal and subcostal branches of the thoracic aorta, the internal thoracic and supreme intercostal branches of the subclavian artery and the superior and lateral thoracic branches of the axillary artery. The venous drainage of the thoracic wall is by the intercostal and subcostal veins.

LATITUDES AND LONGITUDES OF THORAX

The globe has latitudes and longitudes. Similarly, the thoracic cage also can be described to have latitudes (lines or spaces of importance on the transverse aspect) and longitudes (lines or spaces of importance on the vertical aspect). The latitudes are provided by ribs and intercostal spaces (spaces or gaps between the ribs). An internal structure can be described to be present 'at the level of nth rib' or 'at the level of nth intercostal space'.

The longitudes are provided by several imaginary lines. The following lines are important:

- ***Midsternal line:*** As the name indicates, this is the midline of the body on the anterior chest wall; it can be defined as the intersection of the midsagittal plane with the anterior chest wall; it is otherwise called the ***anterior median line***.
- ***Midclavicular line:*** This is the vertical line drawn from the midpoint of clavicle down the anterior chest wall.
- ***Anterior axillary line:*** This is the vertical line drawn along the anterior axillary fold and continued down the chest wall.
- ***Posterior axillary line:*** This is the vertical line drawn along the posterior axillary fold and continued down the chest wall.
- ***Midaxillary line:*** This is the line drawn from the deepest part of the axillary fossa down the chest wall, parallel to the anterior axillary line.
- ***Midvertebral line:*** This is the line drawn along the spines of vertebra and is the midline of the body on the posterior aspect; it is also called the ***posterior median line***.
- ***Scapular line:*** This is the line drawn along the inferior angle of scapula; it is parallel to the midvertebral line.

Multiple Choice Questions

1. The constituent ribs of the inferior thoracic aperture are:
   a. The pair of 12th ribs
   b. The 11th and 12th ribs of both sides
   c. The 12th ribs and the 7th ribs of both sides
   d. The 10th , 11th and 12th ribs of both sides

2. Which feature of the thoracic cage is a sequel to the erect posture of humans?
   a. A conical shape
   b. Anteroposterior flattening
   c. Irregular inferior aperture
   d. Crowding of the thoracic outlet

3. Why is the superior thoracic aperture called the thoracic outlet?
   a. Because air and food passages enter through this opening
   b. Because it is often involved in thoracic outlet disease
   c. Because important vessels and nerves emerge out of this aperture
   d. It is the largest of the thoracic openings

4. Apart from the pectoral region and the mammary gland, which other group of structures of the chest wall is not included in the thorax?
   a. The skin and fascia of anterior chest wall
   b. The skin, fascia and muscles of the posterior aspect
   c. The skin, fascia and muscles of the anterior aspect
   d. The contents of axilla

5. The scapular line will intersect:
   a. The acromion
   b. The inferior scapular angle
   c. The medial border of scapula
   d. The spinoacromial angle

ANSWERS

1. a **2.** b **3.** c **4.** b **5.** b

Clinical Problem-solving

Case Study 1: When you visited your friend, you happened to see his brother lying supine on the floor as part of his exercise routine. Your friend commented that 'lying supine' is essentially a human feature.

- Do you agree with your friend?
- If so, what is your reason for such a comment?
- What are the additional modifications in relation to this particular feature?

Case Study 2: A 42-year-old man had pain down his upper limb and also some neurovascular symptoms. He was diagnosed to be having 'thoracic outlet syndrome'.

- What do you understand by the term?
- What are the boundaries of the thoracic outlet?
- What are the various causes for thoracic outlet syndrome?

(For solutions see Appendix).

Chapter 2

General Characteristics of Vertebral Column

Frequently Asked Questions

- Write notes on: (a) Regions of the vertebral column, (b) Structure of a typical vertebra, (c) Intervertebral disc, (d) Disc prolapse.
- Give an account of the vertebral column and its curvatures.
- Discuss the structure and functions of nucleus pulposus.

INTRODUCTION

The ***vertebral column***, otherwise called the ***spinal column*** or the ***spine***, is a flexible, curved structure consisting of several irregular bones called the ***vertebrae*** (singular. vertebra; plural. vertebrae). Extending from the skull to the pelvis, it forms the axial support and the weight-bearing system of the body. The vertebral column also surrounds and protects the spinal cord; it gives attachment to several muscles of the neck and back; it provides points of attachments to the ribs, thus contributing to the formation of a bony thoracic cage.

In the foetus and young infant, the vertebral column is made up of 33 separate vertebrae, but the lower nine later fuse to form two composite bones, namely the ***sacrum*** and the ***coccyx***. The upper 24 remain as individual bones separated by the intervertebral discs.

The sheer length of the vertebral column makes it necessary for several other structures to support the column. The various ligaments of the back and the muscles of the trunk provide this support.

REGIONS AND CURVATURES

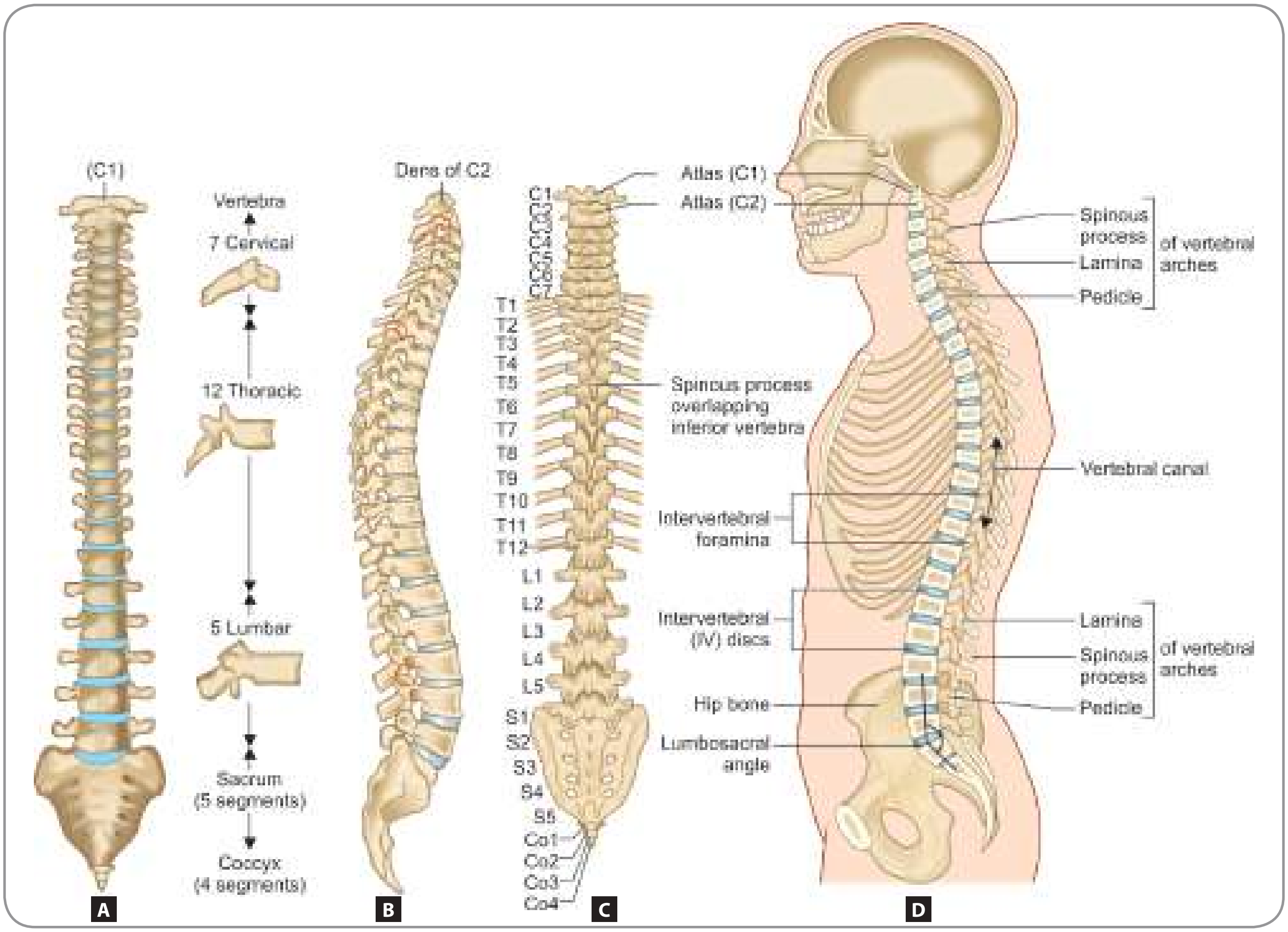
In an average adult, the vertebral column is about 70 cm long. It can be subdivided into five regions, namely (from above downwards) the ***cervical***, ***thoracic***, ***lumbar***, ***sacral*** and ***coccygeal regions*** (Figs 2.1A to D). The first seven vertebrae form the cervical region which is related to the neck. The next twelve vertebrae form the thoracic region which is part of the thoracic cage. The next five are the lumbar vertebrae which support the lower back and form the lumbar region. These upper three regions comprise individual vertebrae. The vertebrae become progressively larger from the cervical to lumbar regions as they have to progressively bear more weight. Lower to the lumbar region is the sacrum, which is the composite bone of the sacral region formed of five sacral vertebrae. The most inferior part of the vertebral column is formed by the coccygeal region that comprises the coccyx, which is a composite bone formed of four coccygeal vertebrae.

From a lateral view, the vertebral column can be seen to have four normal curvatures. These are the cervical, thoracic, lumbar and the sacral curvatures. The cervical and the lumbar curvatures are concave posteriorly while the thoracic and sacral are convex posteriorly. The curvatures are functionally important because they increase the resilience of the vertebral column and allow to function with adequate elasticity. The vertebral column should be like a spring and not like a rigid rod. The curvatures render elasticity for the spring action to take effect.

GENERAL STRUCTURE OF A TYPICAL VERTEBRA

It can well be understood that the size, shape and characteristics of the vertebrae will vary according to the region of the vertebral column. However, most of them share certain common features. These features can be fitted into an imaginary typical vertebra.

A typical vertebra will have two main parts called the ***body*** and the ***vertebral arch***. The body is that part which is anterior and appears like a ***thick disc***. The vertebral arch is posterior and has several projections. The body and the vertebral arch together and between themselves enclose an opening called the ***vertebral foramen*** (Fig. 3.2). When the vertebral bodies are placed one over the other (as in real life), successive vertebral foramina form a ***long vertebral canal*** through which the spinal cord runs.



Figs 2.1A to D: Vertebral column and its five regions **A.** Anterior view **B.** Lateral view **C.** Posterior view **D.** Bisected view with the vertebral column *in situ*

The body is also called the ***centrum***. It is disc-shaped, varies in size in different regions and bears the body weight. Intervertebral discs lie between the bodies of successive vertebrae.

From the posterior aspect of the body, two projections, one on either edge, run backward. These projections are the pedicles. From the posterior ends of each pedicle, a plate of bone stretches towards the midline and unites with the fellow of the opposite side. This plate of bone is the lamina. The two pedicles and the two laminae together form the ***vertebral arch***.

A total of seven processes project from each vertebral arch. At the junction of the two ***laminae*** is the spinous process (or simply the spine). It is a single, midline projection that points posteriorly (or posteroinferiorly). At the junction of the pedicle of each side with its corresponding lamina is the transverse process. Two transverse processes, one from each side, therefore, project laterally from each vertebra. From the pedicle-lamina junctions, but medial to the transverse processes, project two other pairs of processes. One pair projects superiorly and the other inferiorly. These are the superior and inferior articular processes respectively. The superior articular processes have articular facets on their posteromedial aspects and the inferior articular processes on their anterolateral aspects. The superior articular processes of each vertebra form joints with the inferior articular processes of the vertebra which is above it.

The pedicles have notches on their superior and inferior borders. Thus, when successive vertebrae are placed one over the other, the notch of the inferior border of the preceding vertebra and the notch of the superior border of the succeeding vertebra together form a foramen called the ***intervertebral foramen***. The spinal nerves given out by the spinal cord pass through the intervertebral foramina.

INTERVERTEBRAL DISCS

Each intervertebral disc is a cushion-like pad that lies between the bodies of two consecutive vertebrae. It has an inner globular part called the ***nucleus pulposus*** and an outer collar part called the ***annulus fibrosus***.

The nucleus pulposus acts like an elastic ball, enabling the vertebral column to absorb compressive forces.

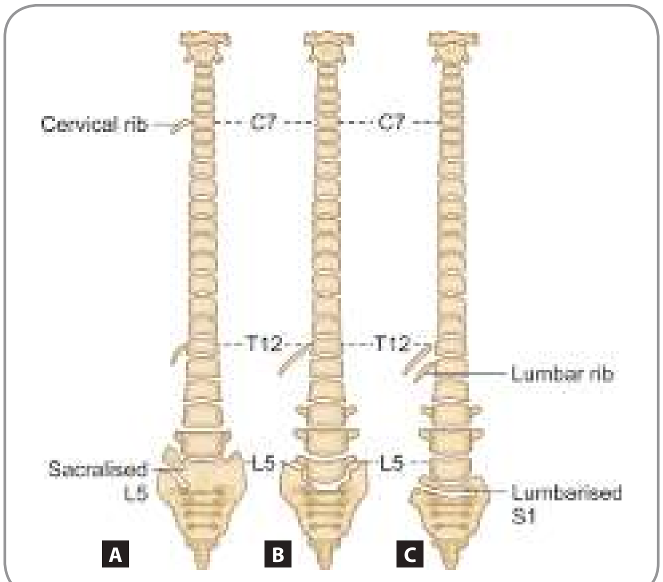
Each annulus fibrosus has about twelve concentric rings within itself. The outer rings are made up of fibrous tissue while the inner ones consist of fibrocartilage. The main function of these rings is to prevent circumferential expansion of the nucleus pulposus. When the vertebral column experiences above downward compression (which happens even in normal weight-bearing due to the erect posture of humans), the nucleus pulposus is compressed from above downwards; due to its elastic nature, it tends to seek the line of least resistance and, therefore, expand circumferentially. The annulus fibrosus, which is placed like a collar around the nucleus pulposus and is less elastic, tends to restrict this expansion and hold the nucleus pulposus in place. The rings of the annulus fibrosus also bind successive vertebrae together and absorb compressive forces.

It can thus be seen that both the parts of the intervertebral disc resist compression and keep the vertebral column in physical and functional competence. The discs act as shock absorbers during movements of walking, running and jumping. They also allow the vertebral column to flex and bend. The discs are thickest in the cervical and lumbar regions (regions of anterior convexities) and this factor gives more flexibility and free movements to these regions. Movements are minimal in regions where the discs are thinnest and these are the thoracic and sacral regions (regions of posterior convexities). In the cervical and lumbar regions, each disc is thicker ventrally than dorsally; in the thoracic and sacral regions, each disc is thicker dorsally than ventrally; thus the discs also contribute to the curvatures of the vertebral column (Figs 2.1B and D).

In life, the intervertebral discs are seen to flatten minimally and bulge out a bit between the vertebrae. About 25% of the total height of the presacral vertebral column is contributed by the intervertebral discs. Due to postural mechanical compression that takes place through the day, the intervertebral discs are little flattened at the end of each day, leading to reduction in the height of the individual by a few centimetres at night when compared to the same on waking up in the morning.

MOVEMENTS OF THE VERTEBRAL COLUMN

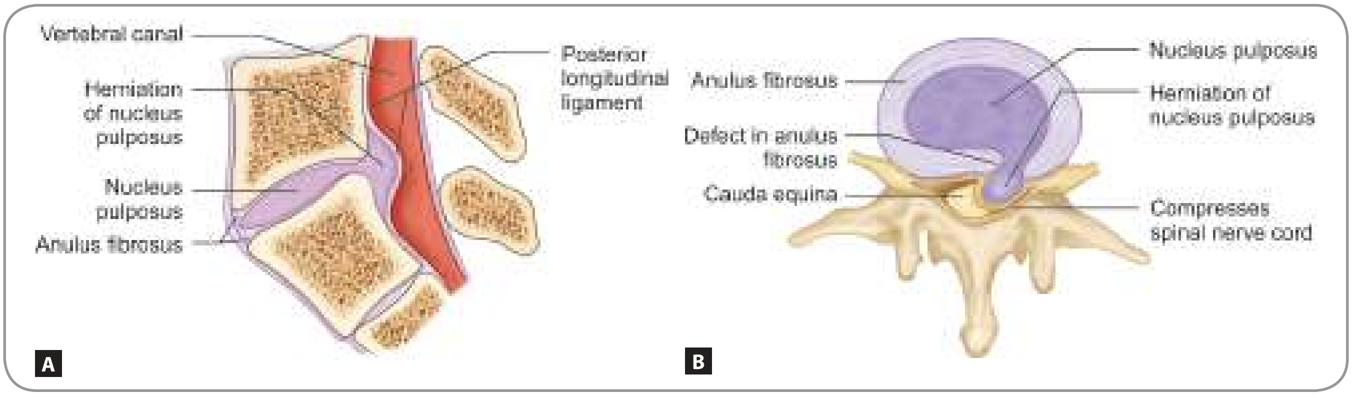
Various movements occur at different levels of the vertebral column. These movements are flexion (anterior or forward bending), extension (posterior or backward straightening), lateral flexion (bending to the right or the left) and rotation (around a vertical axis) (Figs 2.2A to C).



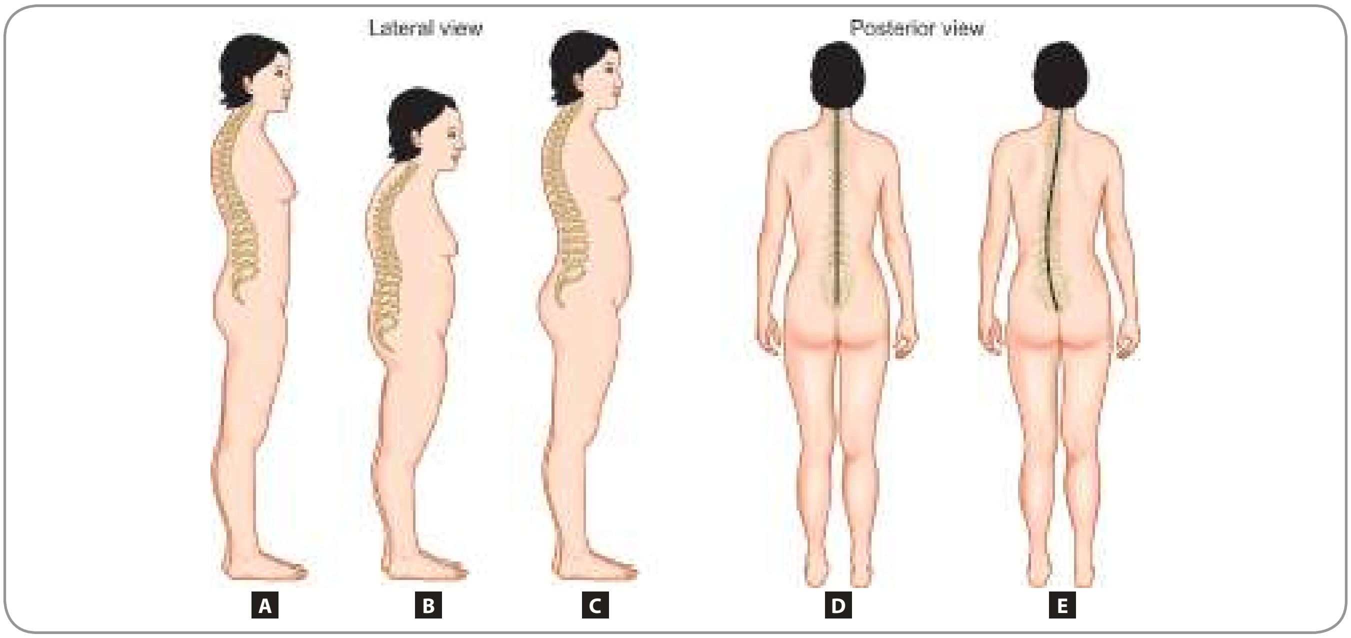
Figs 2.2A to C: Possible variations in the vertebral column **A.** Shows a cervical rib and sacralisation of lumbar vertebra **B.** Shows normal disposition **C.** Shows a lumbar rib and lumbarisation of sacral vertebra

Clinical Correlation

- The nucleus pulposus may protrude through the annulus fibrosus. This condition is called ***disc prolapse*** (Figs 2.3A and B) or ***disc herniation***. The annulus fibrosus is thinnest posteriorly and the nucleus pulposus herniates through this portion. However, due to the presence of the posterior longitudinal ligament, the herniation proceeds posterolaterally towards the spinal nerve roots coming out of the spinal cord. The nerve roots are pressurised leading to pain or numbness. The cause for herniation is a severe or sudden physical trauma to the vertebral column.
- Abnormal spinal curvatures can occur. Some of such abnormal curvatures are congenital while others are due to poor posture, abnormal pull of muscles or diseased conditions. Examples of such abnormalities as shown in Figures 2.4A to E:
  - Scoliosis—abnormal lateral curvature;
  - Kyphosis—exaggerated thoracic curvature where the posterior convexity is increased and causes a hunchback;
  - Lordosis—exaggerated lumbar curvature where there is swayback.
- Temporary lordosis is commonly seen in people carrying a heavy load 'up in front' like while carrying a heavy object, obese individuals and pregnant women. The shoulders are 'thrown back' in order to preserve the line of gravity.
- Lumbar vertebrae experience heavy load and compression, because the weight of the upper body plus the weight of the objects the individual lifts with the upper body will have to be borne by the lumbar region. Since the lumbar region has maximum compression, disc herniation is more in this region.



Figs 2.3A and B: Disc prolapse **A.** Side view **B.** Superior view



Figs 2.4A to E: Lateral and posterior view of abnormalities of spinal curvatures **A.** Normal **B.** Kyphosis **C.** Lordosis **D.** Normal **E.** Scoliosis

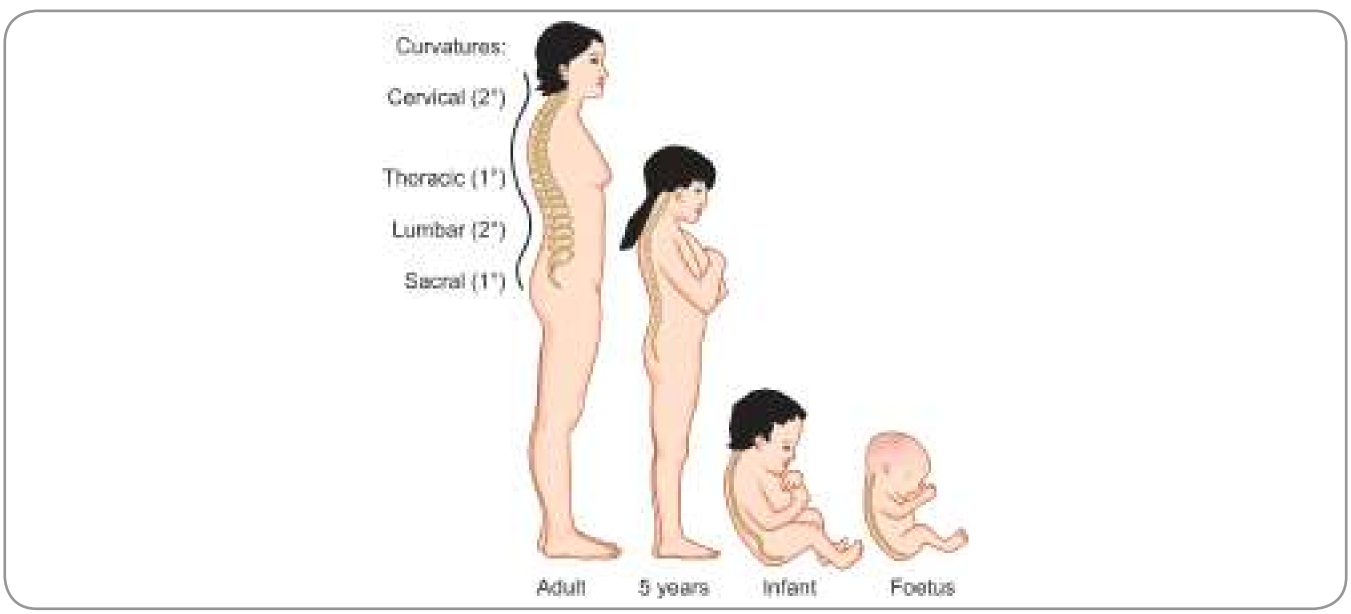


Fig. 2.5: Age changes and development of vertebral curvatures during foetalhood and infancy, only the primary curvatures are seen. The secondary curvatures develop during growth

Added Information

- The weight bearing part of a vertebra is its body which can be compared to a long bone. The body is constricted a little in its midportion (comparable to the shaft) with slight enlargements at the upper and lower ends (the two ends). The two ends are articular; the midportion has a primary centre of ossification (diaphysial primary centre) and the two ends have secondary centres.
- The articular processes (except those of the atlas and the axis) generally do not bear or transmit weight. However, in certain specialised conditions like rising from the stooping position, the articular processes also bear weight.
- The size of a weight-bearing surface depends upon the weight it supports. The lumbar vertebrae, hence, are large and have larger surfaces on the superior and inferior aspects than the thoracic and cervical vertebrae. The first piece of sacrum has a large superior surface. The surfaces then decrease till the tip of coccyx. This is because the body weight which is borne by the presacral vertebral column is transferred from the first three pieces of sacrum to the ilia (through the sacroiliac joints) and then to the femora. The lower sacrum and coccyx do not, therefore, take part in weight-bearing or transmission.
- In prenatal life, the vertebral column is uniformly curved with a ventral concavity. The basic curvature is retained in the thoracic and sacral regions. The cervical curvature appears by about three months of age when the child holds the head erect and learns to direct vision forward. The lumbar curvature appears when the child starts walking which, is around 18 months of age. The thoracic and sacral curvatures which are IN continuation of the prenatal curvature are called the ***primary curvatures***. The cervical and lumbar curvatures, which are acquired postnatally, are called ***secondary curvatures*** (Fig. 2.5).

Multiple Choice Questions

1. The foetal complement of 33 vertebrae become 24 in the adult because of:
   a. Loss of vertebral bodies
   b. Adhesion of upper vertebrae to skull
   c. Fusion of some into composite bones
   d. Shrinkage of intervertebral tissue

2. In the normal curvature of the vertebral column:
   a. The cervical and lumbar curves are concave posteriorly and the thoracic and sacral are concave anteriorly
   b. The cervical and lumbar curves are convex posteriorly and the thoracic and sacral are convex anteriorly
   c. The cervical and sacral are concave posteriorly and the thoracic and lumbar are concave anteriorly
   d. The cervical and sacral are curved and the thoracic and lumbar are straightened

3. In a typical vertebra, the intervertebral foramen is formed between:
   a. Notches in the borders of the pedicles
   b. Notches in the borders of the vertebral arch
   c. Notches in the borders of the bodies
   d. Notches in the borders of the laminae

4. The height of an individual is decreased in the night due to:
   a. Flattening of the vertebrae
   b. Flattening of intervertebral discs
   c. Thinning of nucleus pulposus
   d. Thinning of the vertebrae

5. Direct posterior herniation of the nucleus pulposus is prevented by:
   a. Annulus fibrosus
   b. Posterior longitudinal ligament
   c. Spinal nerve roots
   d. Lumbar lordosis

ANSWERS

1. c **2.** a **3.** a **4.** d **5.** b

Clinical Problem-solving

Case Study 1: A 54-year-old man suffers from L3-L4 disc prolapse.
- Give the anatomical basis of any disc prolapse.
- What symptoms due to expect in the above mentioned individual and why?
- Why is lumbar disc prolapse more common than others?

Case Study 2: A 27-year-old pregnant woman has a prominent lumbar lordosis.
- What treatment measures will you suggest to her?
- Enumerate a few everyday instances where there is 'temporary lumbar lordosis'.

(For solutions see Appendix).

Chapter 3

Bones of Thorax

Frequently Asked Questions

- Discuss the features of a typical vertebra in detail.
- How is a typical thoracic vertebra identified? Elaborate on its special features.
- Discuss the atypical thoracic vertebrae.
- Write notes on (a) Typical rib, (b) First rib, (c) Manubrium sterni, (d) Xiphisternum
- Discuss the various parts of the sternum.

The bones of thorax are placed in such a way that the internal structures like the heart and lungs are well protected. They form the bony thoracic cage, which also contributes in a significant way to the human form.

The ***thoracic cage*** is made up of several bones. In the posterior aspect are the twelve thoracic vertebrae. In the anterior aspect is the sternum. The side walls of the thorax, on either side, are formed by the twelve ribs and their associated costal cartilages (Fig. 3.1).

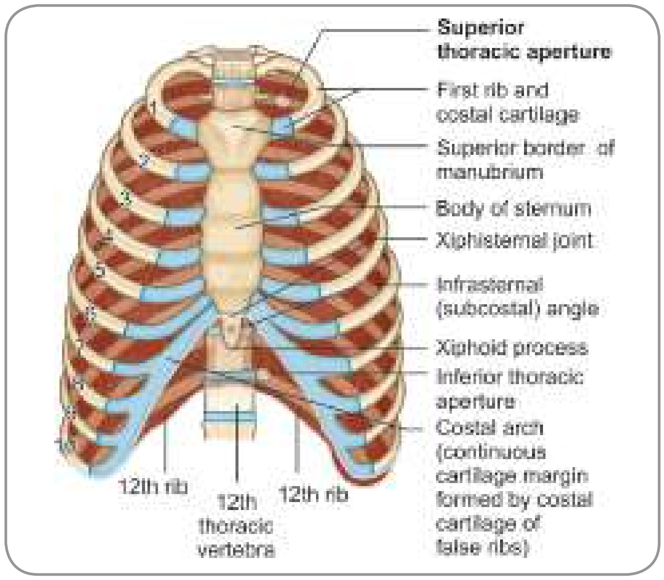


Fig. 3.1: Thoracic cage with the superior and inferior apertures marked out

FEATURES OF A TYPICAL VERTEBRA

Before a study of the thoracic vertebra is taken up, it is necessary to know the features of a typical vertebra (Latin. verto=to turn).

A typical vertebra has the following parts: (a) body, (b) pedicles, (c) laminae, (d) spine and (e) transverse processes (Fig. 3.2).

The body is the anteriorly placed large portion; it looks like a short cylinder, being rounded from side-to-side, and having flat upper and lower surfaces. The upper and lower surfaces are attached to those of the adjoining vertebrae through the intervertebral discs.

Projecting backwards and a little laterally from the right and left aspects of the posterior part of the body are two short bars of bone. These bars are called the ***pedicles***

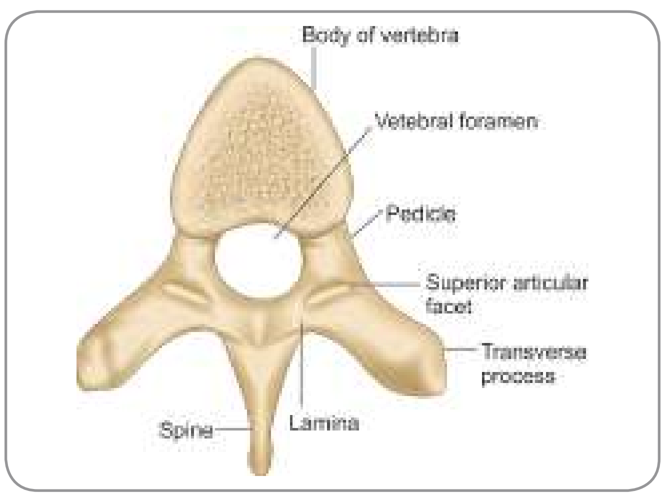


Fig. 3.2: Typical vertebra seen from above

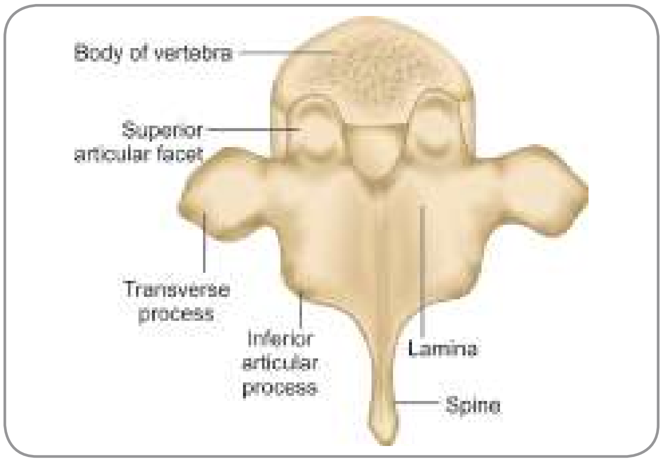


Fig. 3.3: Typical vertebra seen from behind

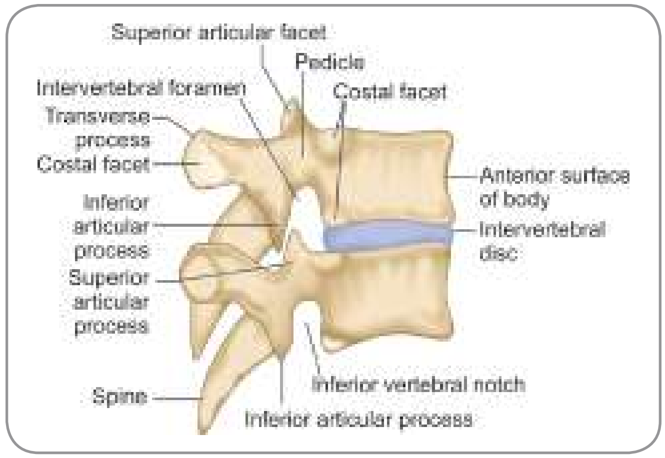


Fig. 3.4: Typical vertebrae seen from the lateral side (costal facets, for ribs, are shown on the bodies and transverses processes they are present only in the thoracic region)

(Latin.pediculus=small feet). Thus, every vertebra has two pedicles, the right and the left. Projecting posteromedially from each pedicle is a plate of bone called the lamina (Latin.lamina=plate). The two laminae meet at the midline. The right and the left pedicles and the right and the left laminae together constitute a bony arch which is called the ***vertebral arch***. Passing backwards and a little downwards from the junction of the two laminae, is the spine (or spinous process) of the vertebra.

From the junction, of each pedicle with its corresponding lamina, projects another bar of bone. This bar, that passes backwards and a little laterally, is called the ***transverse process*** (Fig. 3.3).

Apart from the various parts, a vertebra also exhibits certain special and unique features. As the vertebral arch curves around, an opening is formed on the posterior aspect of the vertebra. This large opening, which is bounded anteriorly by the posterior aspect of the body, laterally by the pedicles and posteriorly by the laminae, is called the ***vertebral foramen***.

From the junction of a pedicle and its corresponding lamina (medial to the root of the transverse process) projecting upwards is the superior articular process and projecting downwards is the inferior articular process. Each process bears a smooth articular facet. The superior articular facet on the superior articular process is directed posteriorly and the inferior articular facet on the inferior process is directed anteriorly. Thus there are two superior facets (right and left) and two inferior facets (right and left) in each vertebra. The superior facets of a vertebra articulate with the inferior facets of the preceding vertebra (vertebra above). Two adjoining vertebrae, therefore, articulate with each other at three joints; two between the superior and inferior articular facets (right and left) and one between the bodies of the vertebrae through the intervertebral disc (Fig. 3.4).

The height of the pedicle is much lesser when compared to the height of the vertebral body. The pedicle is also attached closer to the upper border of the body. Two notches are therefore seen (when the vertebra is viewed from the sides), one above and another below the pedicle. The one above, called the superior vertebral notch, is shallow. The inferior vertebral notch is large and deep. When the adjoining vertebrae are placed one above the other, the inferior notch of the preceding vertebra and the superior notch of the succeeding vertebra complement each other and form a foramen called the intervertebral foramen. Between any two vertebrae are two intervertebral foramina, one on the right and the other on the left.

The vertebral foramen of each vertebra is a short segment of the vertebral canal that runs through the whole length of the vertebral column and transmits the spinal cord. As the spinal nerves emerge out of the spinal cord, the right and the left spinal nerves of a particular spinal segment pass through the right and the left intervertebral foramina.

THORACIC VERTEBRAE

The thoracic vertebrae are twelve in number and form part of the skeleton of the thorax. All of them do not have the same features. The second to the ninth thoracic vertebrae possess features characteristic of a thoracic vertebra and hence are examples of a ***typical thoracic vertebra***. The first, tenth, eleventh and twelfth thoracic vertebrae have features which do not confirm to those of a typical thoracic vertebra, but distinguish the particular vertebra. These are called the ***atypical thoracic vertebrae***.

Typical Thoracic Vertebrae

The thoracic vertebrae have features which make them rib-bearing and hence suitable for formation of the thoracic cage. The bodies of the thoracic vertebrae in the mid thoracic region are heart shaped. Each body is longer on the posterior aspect than the anterior aspect so that the vertebral column is concave anteriorly (in the thoracic region). The upper and lower surfaces are flat; the surface areas progressively increase from T1 to T12. The left sides of the bodies of thoracic vertebrae 5, 6 and 7 are flattened by the aorta.

On each side of the body and close to the root of pedicle are a pair of articular facets, one on the upper border and the other on the lower border. These facets are not complete in the sense that the head of the rib which articulates with one of these facets will also articulate with a similar facet on the vertebra above or below. These facets, therefore, are called ***demifacets*** (or costal demifacets; Latin.costa=rib). The upper facet is larger than the lower and articulates with the numerically corresponding rib (also called the vertebra's own rib). The lower facet articulates with the succeeding (next lower) rib.

The transverse processes of thoracic vertebrae are large and have blunt tips. They are directed backwards and laterally. Each process bears a prominent articular facet on the anterior aspect of its tip for articulation with the tubercle of the numerically corresponding rib (Fig. 3.5). The transverse processes become progressively shorter from the first to the twelfth vertebra. The spinous processes are long and project downwards. When all the thoracic vertebrae are in place, each preceding spine overlaps its succeeding spine, thus contributing to the stability of the thoracic vertebral column.

The superior articular facets face posterolaterally and the inferior facets face anteromedially. The superior vertebral notches are practically absent and the inferior notches are deep and large.

Atypical Thoracic Vertebrae

First Thoracic Vertebra – T1

The first thoracic vertebra has a small body which is oval in shape, similar to that of a cervical vertebra. The posterolateral parts of the body are raised (as in cervical vertebrae) (Figs 3.6 and 3.7) and as a result a definite superior vertebral notch can be identified (This notch is almost absent in other thoracic vertebrae) (Fig. 3.8). The superior costal facets on the body are usually complete as the first rib articulates wholly with this vertebra. The superior articular facets face posterosuperiorly and not posterolaterally. The spine is long and more or less horizontal (Fig. 3.8). The vertebral foramen is triangular.

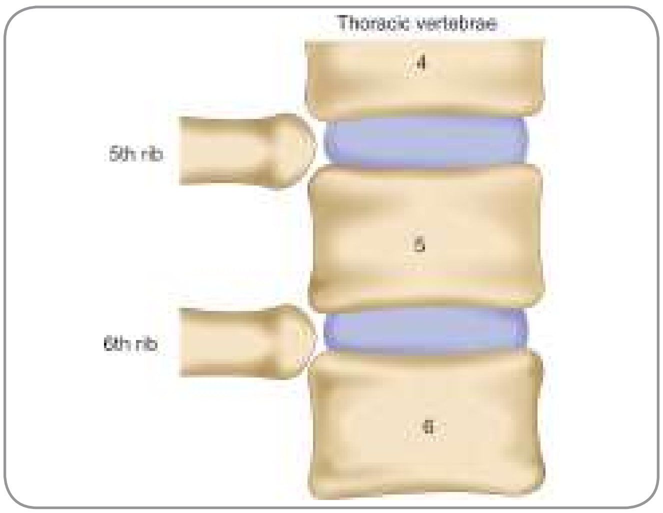


Fig. 3.5: Scheme showing the numerical relationship of thoracic vertebrae to ribs

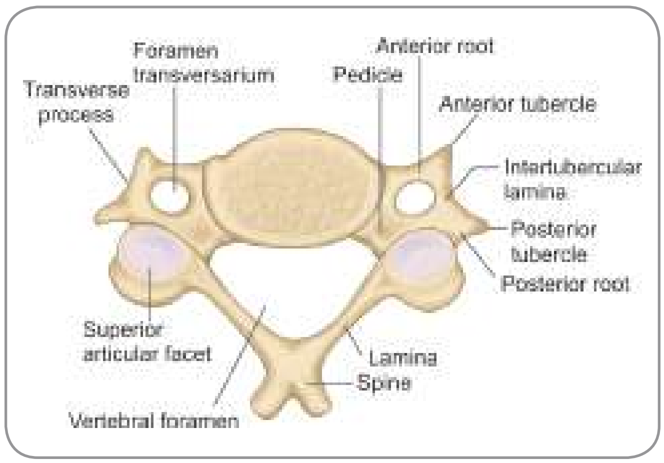


Fig. 3.6: Typical cervical vertebra seen from above

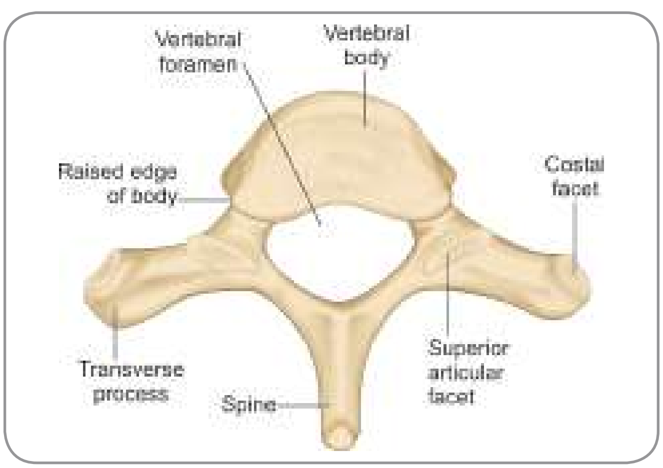


Fig. 3.7: First thoracic vertebra seen from above

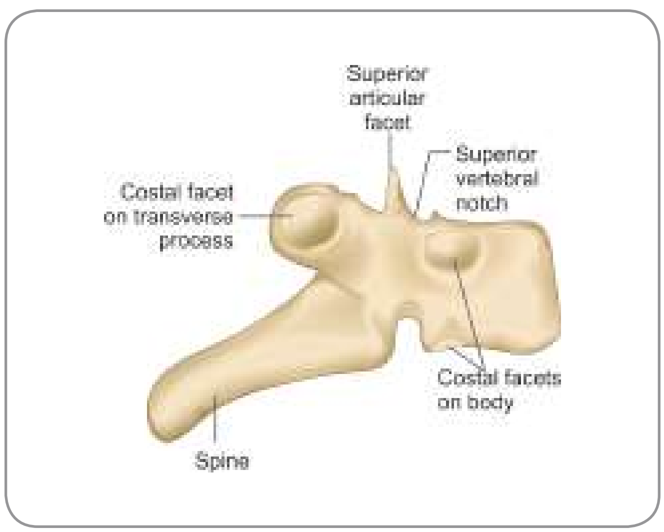


Fig. 3.8: First thoracic vertebra seen from the lateral side

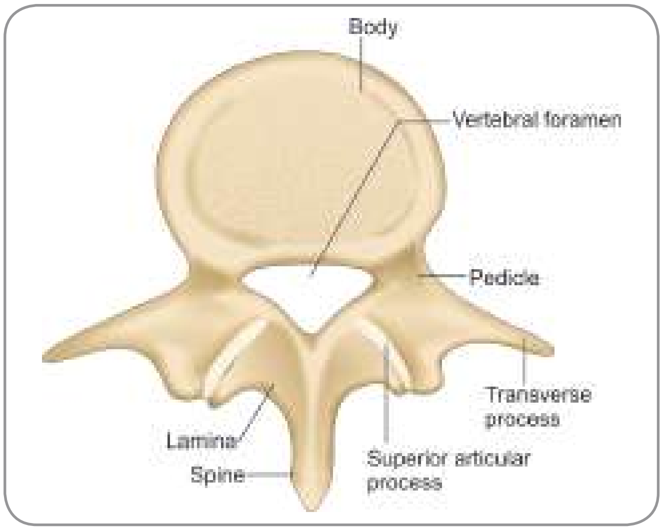


Fig. 3.9: Typical lumbar vertebra seen from above

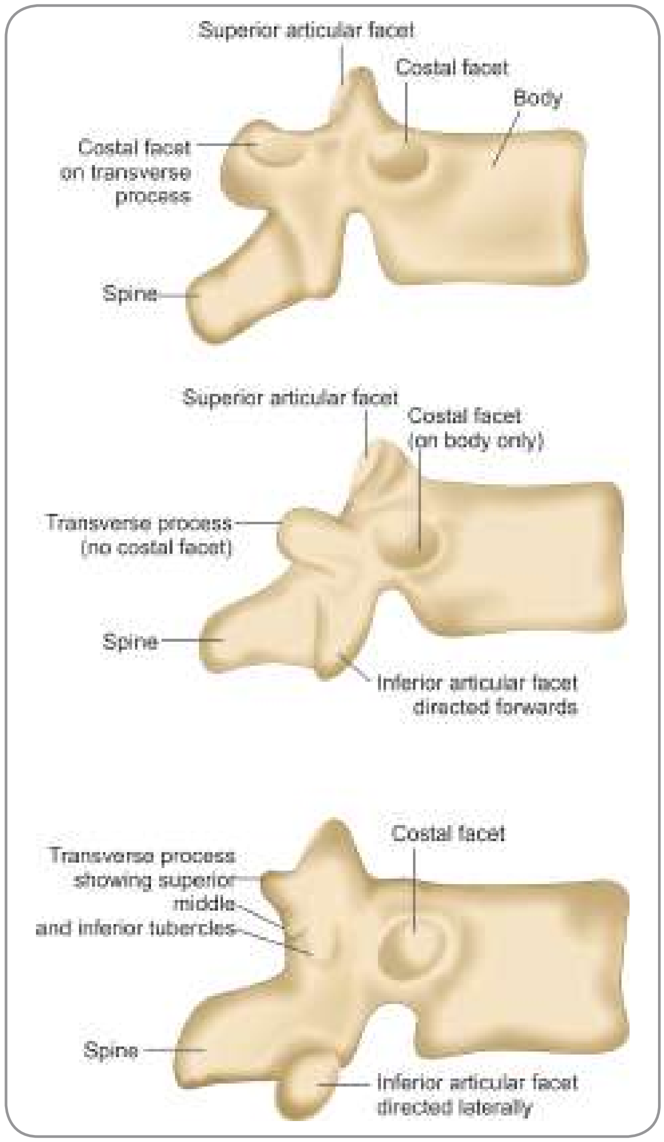


Fig. 3.10: Tenth, eleventh and twelfth thoracic vertebrae from the sides

Tenth, Eleventh and Twelfth Thoracic Vertebrae

The tenth, eleventh and twelfth thoracic vertebrae tend to resemble the lumbar vertebrae (Fig. 3.9) in the shape and size of their bodies, of the vertebral foramina, and of the spines. They are distinguished from typical thoracic vertebrae by the fact that they have only one costal facet on each side of the body. Though the facets on the 10th vertebra remain on the body, those on the 11th and 12th encroach onto the pedicles. The lower demifacet on the 9th vertebra is usually absent since the 10th has a complete facet for the 10th rib (Fig. 3.10).

The transverse process of the 10th thoracic vertebra is large as can be seen in typical thoracic vertebrae and has a flat costal facet usually above the tip of the transverse process. Facets on the transverse processes are absent in the 11th and 12th vertebrae. In addition, the transverse processes of the 12th vertebra consist only of three tubercles (superior, inferior and lateral).

The 11th and 12th vertebrae can be distinguished from each other by examining the inferior articular facets. These are of the thoracic type (facing posterolaterally) in the 11th vertebra, but are of the lumbar type (facing laterally) in the 12th vertebra (Fig. 3.9).

Ninth Thoracic Vertebra

The ninth thoracic vertebra has all features of a typical thoracic vertebra. However, it very often does not articulate with the tenth ribs and so, the inferior demifacets are absent (or very small).

Development

In the early embryo, the paraxial mesoderm gets organised into bilateral segmental masses called ***somites***. Somites of head and tail regions degenerate or go through atypical

contd…

Development *contd…*

development. Somites of cervical and trunk regions show typical development. Vertebrae and associated structures develop from this.

Each somite differentiates into three portions—a dorsal superficial portion called ***dermatome***; a lateral portion called the ***myotome***; a medial portion called the ***sclerotome***.

It should be remembered that the notochord is already in the midline. Scterotomic cells from both the sides migrate medially and surround the notochord. By the 5th week of intrauterine life, the notochord lies within this axial sclerotomic tube which still has its segmentation intact.

Each segmental mass of the sclerotomic tube now undergoes partial differentiation; caudal portion becomes densely condensed and cranial portion is less condensed. The caudal dense portion moves cranially to reach the level of the centres

contd…

Development *contd...*

of the corresponding myotomes. This cranially relocated dense portion differentiates further into the ***intervertebral disc and intervertebral ligaments (Fig. 3.11)***.

Movement of the dense portion of the sclerotomic mass splits the less condensed portion into cranial and caudal subparts. The caudal subpart of one segmental mass unites with the cranial subpart of the succeeding segmental mass and forms the vertebral body and the transverse processes.

At subsequent stages, a pair of chondrification centres appear in the body portion (centrum) and fuse to form the precartilaginous vertebral body; chondrification centres appear in each half of the neural arch, grows around dorsally and fuses with the opposite fellow around the neural tube; the body centres and neural arch centres unite and also extend laterally to form the transverse processes.

Ossification centres will later appear in the same pattern and complete the formation of vertebrae; but this process takes place much later, resulting in complete vertebral formation only after birth.

The notochord which gets trapped in the centrum postion (dense sclerotome) degenerates completely. In the intervertebral regions, it enlarges and forms the nucleus pulposus. The (less dense) sclerotomic tissue that surrounds the notochord in the intervertebral regions forms the rest of the intervertebral discs and the intervertebral ligaments.

Added Information

- Among the spines of the twelve thoracic vertebrae, four lie above the level of the pericardium, four behind it and four below it. The spines which are behind the pericardium (5th, 6th, 7th and 8th) are almost vertical and overlap the succeeding spine. Their tips are at the level of the lower border of the body of the vertebra immediately below.
- The spines of the 1st , 2nd, 11th and 12th vertebrae are almost horizontal. Those in between the two groups (vertical and horizontal), namely 3rd, 4th, 9th and 10th are oblique.
- The superior and inferior articular processes are set on the arc of a circle which, if drawn, completely, has its centre in the vertebral body. Because of this, movements between adjacent thoracic vertebrae are rotary in nature.
- The thickness of the thoracic intervertebral discs is less when compared to the cervical and lumbar regions and hence the range of movements in the thoracic vertebral column is also less.
- The costal facets in the transverse processes of 1–7 thoracic vertebrae are concave and on the anterior aspects of the tips of the transverse processes; those of the 8–10 vertebrae are flat and above the tips; they are absent in the 11th and 12th vertebrae.
- The vertebral foramina of the thoracic region are circular and small. However, in the upper and lower two thoracic levels, they become triangular.

Dissection

Take samples of different ribs. Keep them adjacent to each other and study their features. Note the differences. Try to identify the various ribs.

Study the sternum and vertebrae.

See the way all these bones are placed in an articulated thoracic cage. Attempt to study the ribs and sternum in a thin live individual as their impressions are seen on the surface.

STERNUM

Other names: Breast bone, Chest bone.

The sternum (Greek.sternon=chest) lies in the anterior wall of the thorax, in the midline. It is elongated vertically, almost flat and about 15 to 20 cm in length (Fig. 3.12). It extends from the root of the neck to the upper level of the anterior abdominal wall. Though generally spoken of as a single bone, it has three parts, namely, the manubrium sterni, the corpus sterni and the xiphisternum. Since it is flat, it has anterior and posterior surfaces. The sternum can be felt through the skin in its whole length and articulates on each side with the clavicle and upper seven costal cartilages.

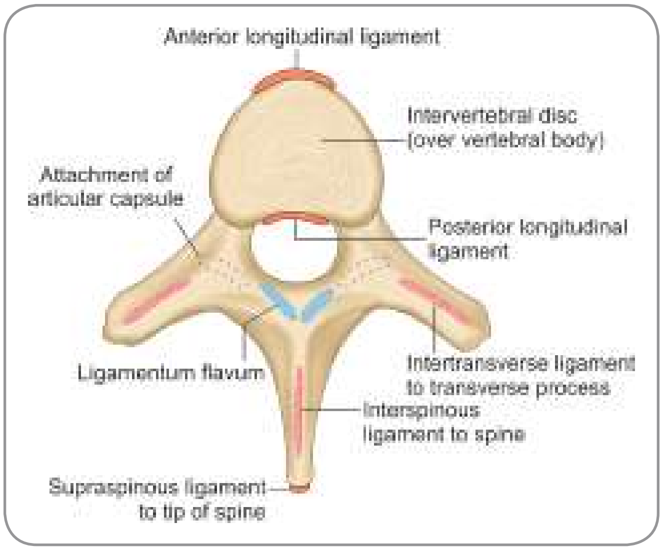


Fig. 3.11: Scheme to show the position of various ligaments interconnecting adjoining vertebrae

Manubrium Sterni

Otherwise called episternum. If the entire sternum is likened to a broad sword, manubrium (Latin. Manubrium=handle) is the handle of the sword. It is roughly quadrilateral in shape, with the upper lateral corners being pulled out more than the rest of the lateral borders. Superior, inferior and two lateral borders can be described and two surfaces, namely the anterior and the posterior.

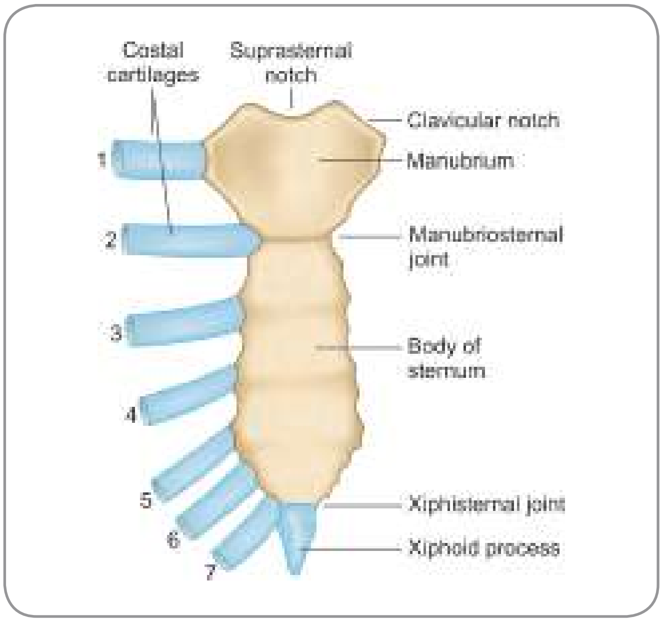


Fig. 3.12: Sternum and costal cartilages seen from front

The middle portion of the superior border is thick, concave from side to side and is called the ***jugular*** (or suprasternal) ***notch*** (Fig. 3.12). Lateral to this, on each side is another notch called the ***clavicular notch***. The medial end of the clavicle articulates here to form the sternoclavicular joint. The superolateral angles, as already noted, are pulled out and rough to receive the first costal cartilage. From the superolateral angle, the lateral margin curves medially to meet the inferior border; the junction of the lateral and inferior borders has a half facet for articulation with the second costal cartilage. The inferior border joins the superior border of the body to form the ***manubriosternal joint***.

At the manubriosternal junction, the edges of both manubrium and corpus sterni are thickened and the two parts are set at an angle; the manubrio sternal junction thus projects forwards, forming the sternal angle. The angle is very easily felt in all individuals and therefore, forms a surface landmark.

Corpus Sterni

This is more commonly called the body of sternum (Latin. Corpus=body). It is composed of four segments called the ***sternebrae***. Put together, the total length of the body is about twice that of the manubrium. From approximately 2.5 cm at its superior border, the body widens to reach about 4 cm at the 4th segment and then tapers rapidly to the inferior border. Similar to the manubrium, two surfaces, the anterior and the posterior and four borders, the superior, the inferior and the two lateral, can be defined. The anterior surface is rough and has three transverse ridges which mark the lines of union of the sternebrae. The posterior surface is smooth and is slightly concave in its long axis. The superior border forms the manubriosternal joint at the sternal angle. The inferior border joins with the xiphisternum forming the xiphisternal joint. The lateral borders have articular facets for the costal cartilages. The uppermost articular half facet on the lateral border is for the 2nd costal artilage which is shared with the manubrium. The 3rd, 4th and 5th costal cartilages articulate opposite lines of union of the sternebrae, thus being shared by first and second, second and third, third and fourth sternebrae respectively. The lateral borders of the 4th sternebra have a small pit for articulaton of the sixth costal cartilage. The seventh costal cartilage articulates at the junction between the body and the xiphoid.

Development

Ribs and Sternum

At about the same time, chondrification is happening in the axial sclerotomic tube, chondrification also occurs in the membranous areas of the future costae along the mesodermal tissues around the body wall. These elements form the ribs and develop fully well in the thoracic region.

As the costal bars grow around the body wall of the concerned side (right or left), in the thoracic region where they are well developed, a longitudinal cartilaginous bar grows to unite all the ventral growing ends of these costal bars. With completion of the side to side folding of the embryo and completion of body wall formation near the stomatodaeum, the two longitudinal bars which lie side by side start uniting. This is the region of the superior thorax; fusion at the upper end results in manubrium sterni; subsequent fusion follows sequentially with the sternal body formed by the 8th week and xiphoid by the 9th week. Complete fusion may not occur in the xiphoid region resulting in forked or perforate xiphoid.

Xiphisternum

Also called the xiphoid (Greek.xiphos=sword) process. It is usually a piece of cartilage which ossifies slowly and joins the body after middle age. It is variable in shape with perforations in the middle. It is thinner than the body and is set flush with the body's posterior surface. The depression formed because of this is the epigastric fossa or the pit of the stomach.

The ***manubriosternal joint*** is a symphysis. After fusion of the body and the xiphoid, the ***xiphisternal joint*** (Fig. 3.12) is said to be a symphysis. However, unlike a typical symphysis, the joint disappears in old age and the xiphoid process and the body of the sternum become united by bone. The junction of the first costal cartilage with the manubrium is a synchondrosis. The other sternocostal joints usually have a joint cavity (i.e., they are synovial joints).

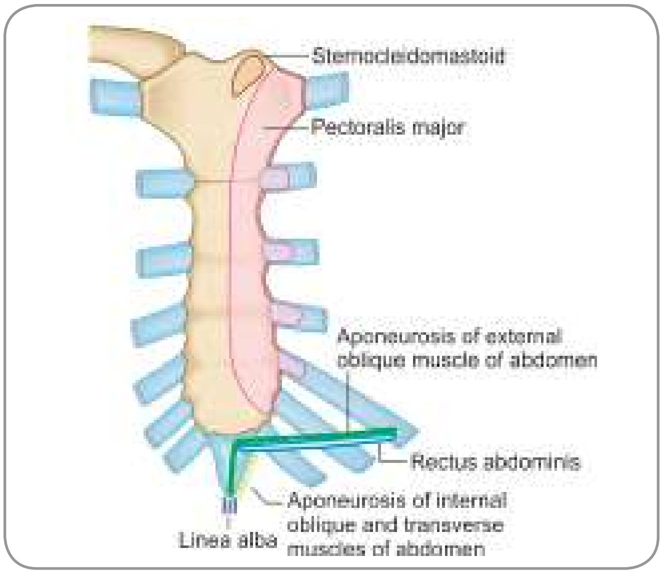


Fig. 3.13: Attachments on the anterior aspect of sternum

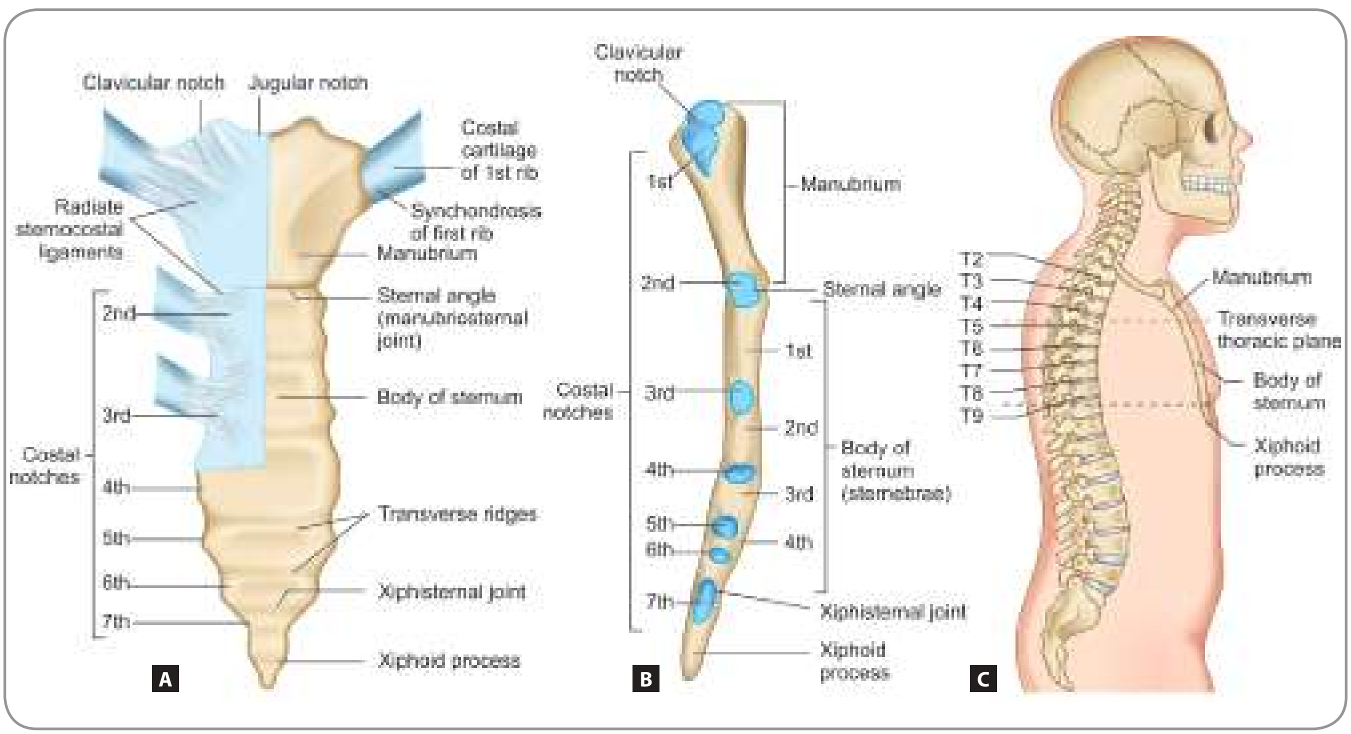
Attachments on Sternum

Structures Attached to the Anterior Aspect of the Sternum (Fig. 3.13)

- Sternal head of ***sternocleidomastoid*** arises from the upper part of the manubrium;
- ***Pectoralis major*** arises from the corresponding half of the manubrium and of the body of the sternum. The origin extends onto the costal cartilages (Figs 3.14A to C);
- Some fibres of the ***interclavicular ligament*** may be attached to the superior border of manubrium.
- ***Rectus abdominis*** is inserted into the xiphoid process. The insertion extends to the 7th , 6th and 5th costal cartilages (in that order) along a horizontal line;
- Aponeurosis of ***external oblique*** muscle of the abdomen, which covers the Rectus abdominis, is attached just beyond the insertion of the latter;
- Aponeurosis of ***internal oblique*** muscle of the abdomen, and of the Transversus abdominis, are attached to the sides of the xiphoid process;
- ***Linea alba*** is attached to the apex (lower end) of the xiphoid process.

Structures Attached to the Posterior Aspect of the Sternum (Fig. 3.15)

- The ***sternohyoid*** arises from the upper part of the posterior surface of the manubrium. The area extends onto the back of the clavicle;
- The ***sternothyroid*** arises from the posterior surface of the manubrium, below the origin of the sternohyoid. The origin extends onto the first costal cartilage;
- The ***sternocostalis*** arises from the lower one-third of the posterior surface of the body, and of the ***xiphoid process*** (and also from the adjoining parts of the costal cartilages);
- Sternal slips of the diaphragm arise from the back of the ***xiphoid process***.



Figs 3.14A to C: Sternum and its parts–attachments of costal cartilages and the costal notches are shown; the relationship of the sternum to the vertebral column are also shown

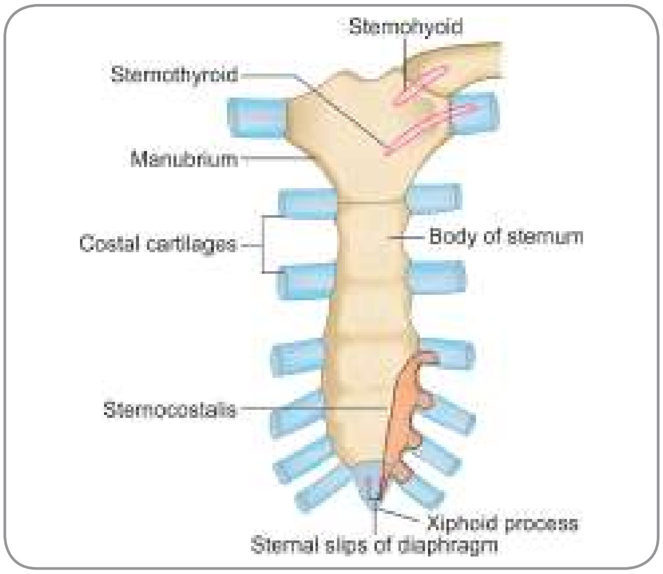


Fig. 3.15: Attachments on the posterior aspect of sternum

Added Information *contd...*

- The first ribs, the first costal cartilages and the manubrium form a single entity and there is no movable joint between these five elements.
- The manubrium is about two inches long, which is about the length of two vertebrae. Its upper border lies at the level of the lower border of T2 vertebra. The lower border corresponds to the level of the upper border of T5 vertebra and the interval between the 3rd and the 4th spines.
- Traced laterally, the sternal angle corresponds to the 2nd costal cartilage.
- The sternebrae are united by cartilage up to the age of puberty, but fuse thereafter to form a single bone.
- The xiphisternal joint is level with the T 9 vertebra and the tip of the 8th spine.
- The sternum as a whole slopes antero-inferiorly.
- The manubriosternal joint plays an important role in respiration. It permits the body of sternum to move forwards and backwards like a hinge and thus assist in altering dimensions of the thoracic cavity.

Relations

As the sternum forms the part of the anterior wall of the thorax, it has very important relations on its posterior aspect. The posterior aspect of the manubrium is related to the arch of the aorta and its branches, and to the left brachiocephalic vein. Its lateral part is related to lungs and pleura. The body of the sternum is also related to lungs and pleura and to pericardium. The xiphoid process is related to the liver.

Ossification

The number of centres of ossification appearing in different segments of the sternum is variable; 1 to 3 in the manubrium and one or two in each sternebra. The centres for manubrium usually appear around the 5th month of intra uterine life. The sternebrae and the xiphoid develop from the right and left mesenchymal bars, which chondrify and fuse in the midline. Then the sternebrae start ossifying. Ossification starts in the four sternebrae from above downwards about the 6th, 7th, 8th and 9th months of intrauterine life and fusion occurs below upwards about the 15th, 20th and 25th years. Ossification in the xiphoid process begins around the 3rd year and proceeds during youth. The xiphisternal synchondrosis becomes a synostosis by around middle age.

Added Information

- The first costal cartilage unites the first rib to the manubrium in the same way as an epiphyseal cartilage unites an epiphysis and the diaphysis. It is a synchondrosis.

contd...

RIBS

Ribs are curved long bones that form the side-walls of the thorax. There are twelve ribs on either side. They vary considerably in length. The seventh rib is the longest, those above and below it becoming progressively shorter. Adjacent ribs are separated by ***intercostal spaces***. The ribs are attached behind to the thoracic vertebrae. The anterior ends of the upper seven ribs are attached to bars of cartilage (***costal cartilages***) through which they gain attachment to the sternum. They are called ***true ribs or vertebrosternal ribs or costae verae***. The anterior ends of the eighth, ninth and tenth ribs also end in costal cartilages. However, these cartilages do not reach the sternum, but end by gaining attachment to the next higher costal cartilage. They are, therefore, called ***false ribs or vertebrochondral ribs or costae spuriae***. The anterior ends of the eleventh and twelfth ribs have small pieces of cartilage attached to their ends. These ends are free and these ribs are, therefore, called ***floating ribs or vertebral ribs or costae fluctuantes***. It is customary to label the vertebrochondral and vertebral ribs as floating ribs.

A rib and its cartilage constitute a costa (Latin. coston=rod). Unlike other long bones, ribs are not triangular in cross section and so, are not rigid. They are flattened, have a thin outer compact layer and are highly resilient.

Typical Rib

A typical rib (usually 3rd to 9th ribs) can be described to have the following parts—***vertebral end, body*** and ***sternal end*** (Fig. 3.16).

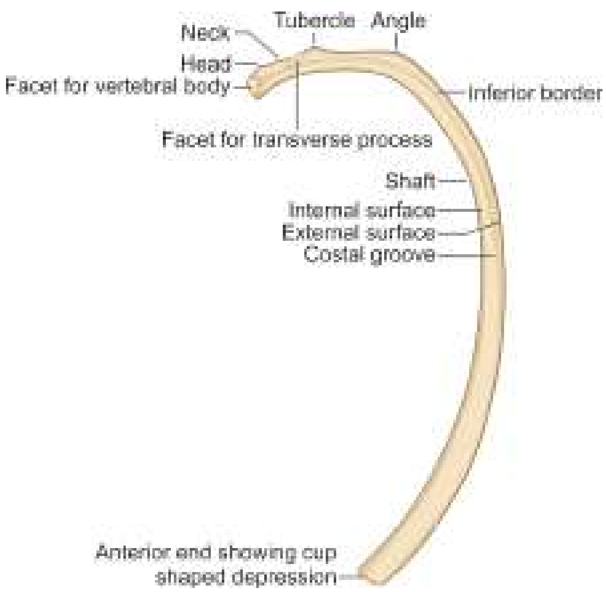


Fig. 3.16: A typical rib seen from below

Vertebral End

The vertebral or the posterior end of a typical rib shows a ***head***, a ***neck*** and a ***tubercle***.

The head articulates partly with the superior costal facet on the body of the numerically corresponding vertebra and partly with the inferior costal facet on the next higher vertebra. It is also attached to the intervertebral disc. The part of the rib immediately lateral to the head is called the neck. It lies in front of the transverse process of the numerically corresponding vertebra. It has a sharp upper border called the ***crest*** of the neck. Just lateral to the neck, the posterior aspect of the rib presents an elevation called the tubercle. The tubercle has a medial articular part that bears a facet for articulation with the costal facet on the transverse process of the corresponding vertebra. The lateral part of the tubercle is rough for attachment of ligaments.

Body

The part of the rib between the anterior and posterior ends is the 'body'; it is also called the ***shaft***. Curved like the letter 'C,' anterior three-fourths of the shaft is also flattened. Thus it has ***inner (internal) and outer (external) surfaces;*** and ***superior (upper) and inferior (lower) borders***.

The upper border is rounded and the lower border is sharp. The internal surface is concave. Just above the lower border, the internal surface shows a ***costal groove*** running along the length of the shaft (Fig. 3.16).

The external surface of the shaft is convex. A short distance lateral to the tubercle, it is marked by a rough line. As the rib appears to be bent at this point, it is called the ***angle***.

The shaft is also somewhat twisted along its long axis. As a result, the external surface faces somewhat downwards in the posterior part and somewhat upwards in its anterior part.

Sternal End

The sternal or the anterior end shows a cup-shaped depression for attachment of the costal cartilage concerned.

Ligamentous and Muscular Attachments to Ribs

The head of each typical rib gives attachment to the fibrous capsule, the radiate ligament and the intra-articular ligament of the ***costovertebral joint***. The neck and tubercle give attachment to ligaments of the ***costotransverse joint***. The superior costotransverse ligament is attached to the crest of the neck, the medial costotransverse ligament to the posterior surface of the neck and the lateral costotransverse ligament to the rough non-articular part of the tubercle.

The lower border and the anterior surface of neck of the rib are attached to the ***internal intercostal membrane.***

- ***External intercostal muscle*** is attached, superiorly, to the sharp lower border of the shaft; and inferiorly to the outer lip of the superior border of the next lower rib.
- ***Internal intercostal muscle*** is attached superiorly to the floor of the costal groove; and inferiorly to the inner lip of the superior border of the next lower rib.
- ***Intercostalis intimus*** (***innermost intercostal***) is attached superiorly to the upper border of the costal groove; and inferiorly to the inner lip of the superior border of the next lower rib (along with the internal intercostal).

The external surfaces of typical ribs give attachment to a number of muscles, the exact attachments varying from rib to rib. These muscles include the ***serratus anterior***, the ***pectoralis minor***, the ***latissimus dorsi***, the ***external oblique*** muscle of the abdomen, the levatores costae, and the iliocostalis cervicis (part of erector spinae).

Important Relations of Typical Ribs

Intercostal vessels and nerve (of an intercostal space) lie in relation to the costal groove, but are separated from the floor of the groove by the internal intercostal muscle. The sympathetic trunk descends vertically across the anterior aspect of the heads of lower ribs. The internal surfaces of the ribs are covered by costal pleura.

Atypical Ribs

Ribs which do not conform to the features of a typical rib are called the atypical or peculiar ribs. The first, second, eleventh and twelfth ribs belong to this category. The tenth rib may sometimes be included.

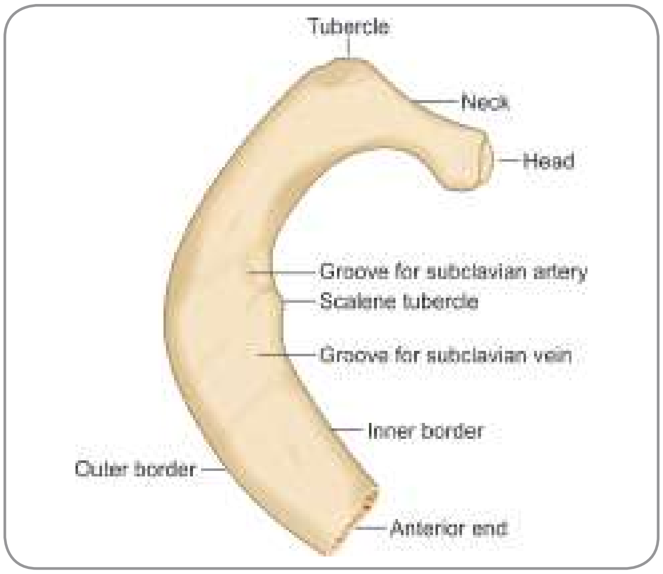


Fig. 3.17: First rib seen from above

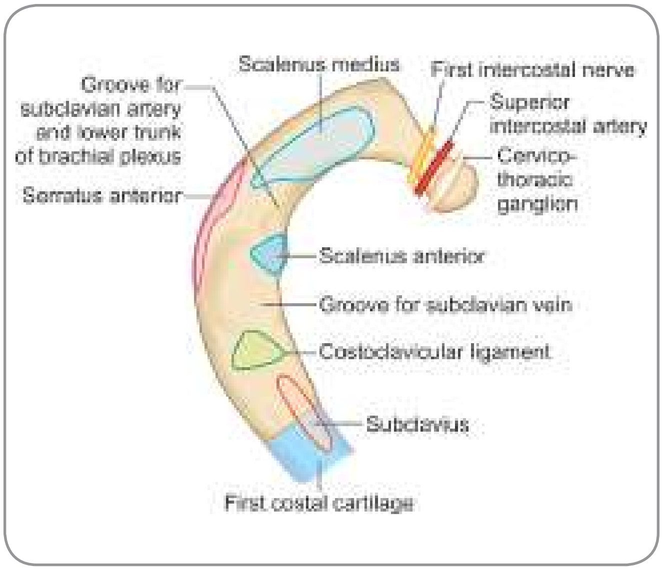


Fig. 3.18: Attachments and relations of first rib seen from above

First Rib

The first rib is a superlative rib, being the highest, shortest, strongest, flattest and the most curved of all (Fig. 3.17). It is small and can be distinguished by the fact that its shaft is broad and flat having superior and inferior surfaces (instead of external and internal), and inner and outer borders (instead of upper and lower). The head has a single facet as this rib articulates only with the first thoracic vertebra. The tubercle is prominent and coincides with the angle. The upper surface of the shaft has two shallow, but wide grooves (for the subclavian vein anteriorly and the subclavian artery posteriorly) (Fig. 3.17). Near the inner border of the rib these two grooves are separated by a prominence called the ***scalene tubercle***. The lower surface of the rib is smooth and does not have a costal groove.

Attachments and Relations of the First Rib (Fig. 3.18)

- ***Scalenus medius*** muscle is inserted into a large rough area on the superior surface, behind the groove for the subclavian artery.
- ***Scalenus anterior*** is inserted on the scalene tubercle, and the adjoining part of the upper surface of the rib.
- ***Subclavius arises*** from the anterior end of the upper surface of the rib; and from the adjoining part of the first costal cartilage.
- The first digitation of the serratus anterior arises from the outer border of the rib near the groove for the subclavian artery.
- The outer border also gives attachment to intercostal muscles of the first space.

The ***costoclavicular ligament*** is attached to the rough area in front of the groove for the subclavian vein. The ***Suprapleural membrane*** is attached to the sharp inner border.

The groove for the subclavian artery lodges this artery, and also the lower trunk of the brachial plexus. The subclavian vein lies in its own groove. The inferior surface of the rib is related to pleura and lung.

Three important structures lie on the anterior aspect of the neck of the first rib. From medial to lateral side these are:

- The sympathetic trunk (***cervicothoracic ganglion***).
- The superior intercostal artery (accompanied by the first posterior intercostal vein).
- The ventral ramus of the first thoracic nerve (which ascends across the first rib to join the brachial plexus).

Second Rib

The second rib can be distinguished from a typical rib by the fact that the entire rib touches it when placed on a flat surface (In a typical rib, the posterior end is lifted off the surface) (Fig. 3.19).

The external surface is directed laterally and upwards (and not directly upwards as in the first rib). Near its middle it has a prominent rough area. The inner surface faces medially and downwards. A short costal groove is present on the posterior part.

Attachments and Relations (Fig. 3.20)

- The upper and lower borders of the rib give attachment to intercostal muscles.
- The ***scalenus posterior*** is inserted into the posterior part of the outer surface.
- The ***serratus anterior*** (first and second digitations) arises from the tubercle on the outer surface just behind the middle of the shaft.
- A slip of the ***serratus posterior superior*** is attached just lateral to the tubercle.

  The inner surface is related to ***lungs*** and ***pleura***.

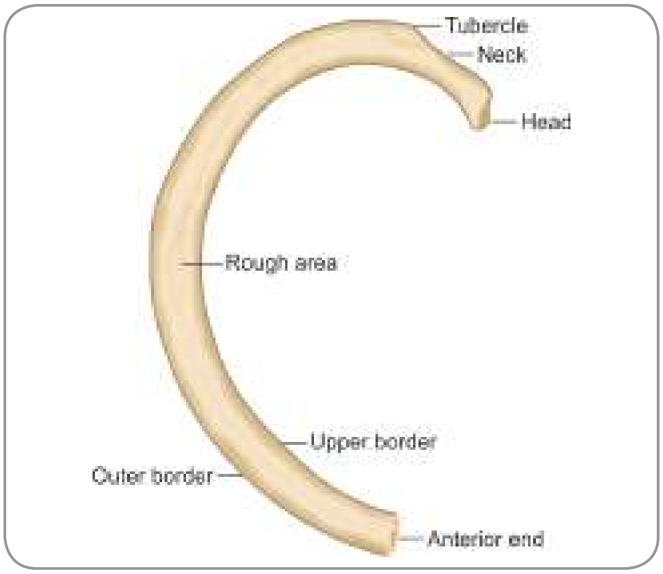


Fig. 3.19: Second rib (right) seen from above

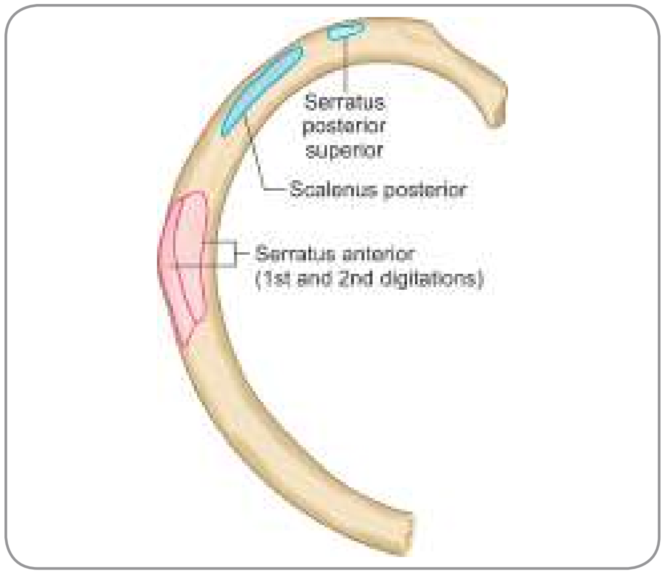


Fig. 3.20: Attachments on the superior aspect of second rib

Tenth Rib

In most respects, the tenth rib is similar to a typical rib. However, very often, it has a singular articular facet on the head, thus making it different. Since the 10th rib may have features resembling both the 9th rib (typical) and the 11th rib (atypical), it is often called a 'transitional' rib. Thus, its head may have two demifacets or a singular facet; its tubercle may be articular or non-articular; its costal cartilage may be united to the ninth costal cartilage by a fibrous strand or be floating.

Eleventh and Twelfth Ribs

These ribs can be distinguished from typical ribs as each of them bears only a single articular facet on the head. This is so because each of these ribs articulates only with the corresponding vertebra. They have large heads, no necks and tubercles and also have pointed ends (Fig. 3.21).

The 11th rib can be distinguished from the twelfth as it has a slight angle and a costal groove which is discernible, but the 12th rib has neither of these features.

Attachments on the Twelfth Rib

- Near the medial end, the 12th rib gives attachment to ligaments of the costovertebral joint and (posteriorly) to the lumbocostal ligament (Fig. 3.22).
- The medial part of the upper border gives attachment to ***intercostal muscles***.

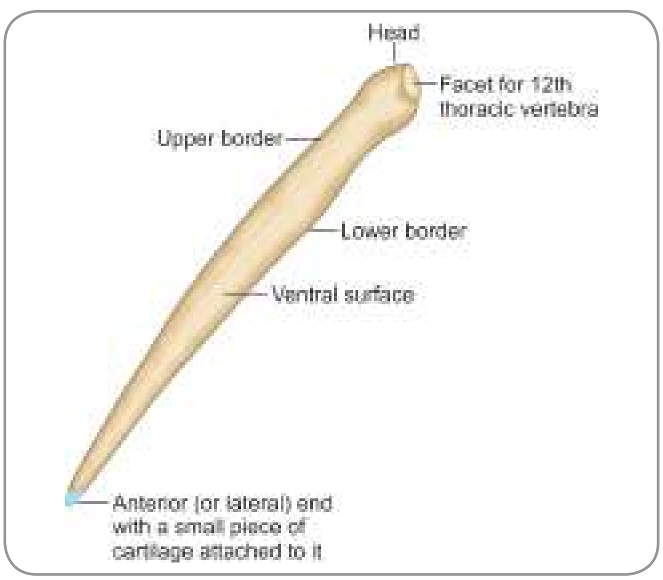


Fig. 3.21: Twelfth rib (right) seen from the front.
Note: Absence of neck, tubercle, angle and costal groove

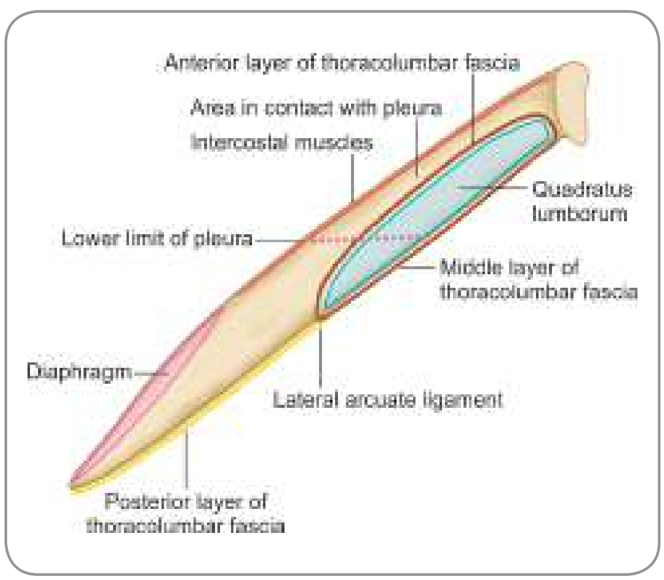


Fig. 3.22: Attachments on the anterior aspect of the twelfth rib

- The ***diaphragm*** is attached to the lateral part of the upper border and to the adjoining part of the anterior surface.
- The ***quadratus lumborum*** is attached to the lower part of the medial half of the anterior surface.
- The layers of ***thoracolumbar fascia*** are attached as follows:
  - The ***anterior layer***, to the anterior surface just above the attachment of the quadratus lumborum.
  - The ***middle layer*** to the lower border just below the attachment of the quadratus lumborum.
  - The ***posterior layer*** to the lower border, lateral to the attachment of the quadratus lumborum (Fig. 3.23).
- The ***lateral arcuate ligament*** is attached to the lower border at the lateral end of the area for attachment of the quadratus lumborum.
- The medial part of the posterior surface of the rib gives attachment to the lowest levator costae and to part of the ***erector spinae*** (Fig. 3.23).
- The lateral part of the posterior surface gives attachment to slips of ***latissimus dorsi***, the ***external oblique muscle*** of the abdomen, and the ***serratus posterior inferior*** (Fig. 3.23).

Relationship of Twelfth Rib to Pleura

The upper part of the medial half of the anterior surface (i.e., the area above that for the quadratus lumborum) is in contact with pleura (costodiaphragmatic recess).

Ossification of Ribs

A typical rib has a primary centre that appears in the shaft, near the angle, during the late second month or early third month (8th or 9th week) of intra-uterine life. Secondary centres (thin and scale-like in appearance) appear around the age of puberty—one for the head, and one each for the articular and non-articular parts of the tubercle. The last mentioned centre is absent in the lower ribs. The secondary centres are all fused by the 24th year of life.

As the eleventh and twelfth ribs have no tubercles the relevant centres are absent in them.

Ossification from the primary centre spreads both forward and backward. However, it fails to reach the anterior sternal end and therefore, this end remains cartilaginous, forming the costal cartilage.

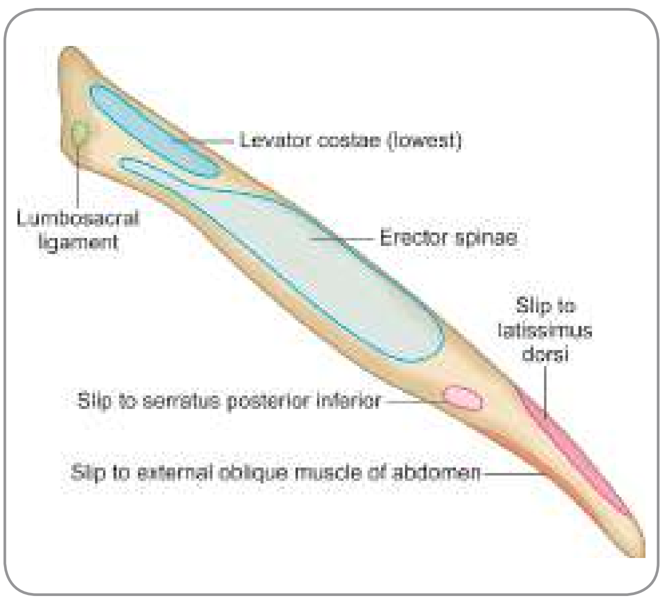


Fig. 3.23: Attachments on the posterior aspect of twelfth rib

COSTAL CARTILAGES

These are bars of hyaline cartilage in the anterior aspects of costae. A typical costal cartilage has medial and lateral ends, anterior and posterior surfaces, and upper and lower borders.

The ***lateral end*** of each costal cartilage is attached to the anterior end of its corresponding rib.

The ***medial ends*** of the upper seven costal cartilages are attached to the lateral margin of the sternum.

- The first costal cartilage is attached to the lateral margin of the manubrium sterni.
- The second costal cartilage is attached partly to the manubrium and partly to the first sternebra.
- The 3rd, 4th and 5th cartilages gain attachment to the lateral edge of the sternum at the points of junction of sternebrae; the 6th on the fourth sternebra; and the 7th at the junction of the fourth sternebra and the xiphoid process.

The medial ends of the 8th, 9th and 10th costal cartilages are connected to the next higher costal cartilage.

The cartilages of the 11th and 12th ribs are small and atypical. They are attached only to the tips of the ribs. As these ribs are very short, the attached end of the cartilage is medial in position and the free ends are lateral.

EVENTS AT THE LEVEL OF STERNAL ANGLE

- Level of junction of T4 and T5 vertebrae;
- Level of junction of superior and inferior mediastinum;
- Termination of ascending aorta, commencement and termination of arch of aorta, commencement of descending aorta;
- Division of pulmonary trunk into right and left pulmonary arteries;
- Division of trachea into right and left principal bronchi and
- Termination of azygos vein by joining the superior vena cava.

Clinical Correlation

Costal cartilages make the wall of the thorax more elastic. Elasticity is lost in old people in whom the cartilages calcify.

Congenital Malformation of Sternum and Ribs

- Some ribs may be underdeveloped or missing. Unilateral absence of a rib is often associated with absence of half of the corresponding vertebral body (***hemivertebra***).
- In a condition called ***ectopia cordis***, the sternum and the adjoining parts of costal cartilages and ribs are missing, so that the heart can be seen from outside.
- Accessory ribs may be present. Such a rib may be attached to the 7th cervical vertebra (***cervical rib***) or to the first lumbar vertebra (***lumbar rib***). Cervical rib is of clinical importance. It usually arises from the transverse process of C7 vertebra and may be connected to the first thoracic rib by a fibrous band or a joint. Structures at the thoracic outlet are already closely packed; the presence of a cervical rib may intervene with the existing space and lead to compression of brachial plexus or subclavian vessels. In such a case, symptoms of thoracic outlet syndrome are produced.
- The first thoracic rib is also clinically important because of its close proximity to the lower nerves of brachial plexus and the subclavian vessels. Normally, the rib is flattened and provides adequate accommodation to the neurovascular structures. However, abnormalities in the rib may cause compression. If the brachial plexus is postfixed, a normal first rib itself may produce compression.
- The sternum develops in right and left halves that normally fuse in the midline. Imperfect fusion leads to partial or complete midline clefts of the sternum.
- Anomalies like bifid ribs and fused ribs can also occur. The sternal end of the third or the fourth rib may be split into two and in such cases, the corresponding costal cartilage is also bifid. On the other hand, adjacent ribs may fuse with each other.
- The eighth costal cartilage may be directly connected to the sternum i.e., it may be an additional true rib. In such case, counting the ribs from the infrasternal angle will go wrong.
- ***Distortion of the thoracic cage:*** The shape of the thorax and its cavity may be distorted by congenital anomalies of the vertebral column, sternum or ribs. Diseases which cause destruction of the vertebral column lead to changes in the curvature of the column and thus cause distortion.

Fractures of Ribs and Sternum

- Ribs can be fractured by direct or indirect (crushing) injury. In a crushing injury, ribs tend to be fractured at their angles (these being the weakest points). As the upper two ribs are protected by the clavicle, injury to them is uncommon. Mobility of the last two ribs protects them from injury.
- Injuries to ribs are rare in children as the thorax is highly elastic in them. However, in children and young adults, where the chest wall is pliable, the underlying structures like the lungs and heart may be compressed. In older age group, the thoracic cage becomes rigid due to calcium deposition in the costal cartilages. The ribs then become brittle and tend to fractures at their weakest points, the angles. Ribs 5 to 10 are more prone to fractures.
- Minor trauma causes the commonest of rib injuries, namely, rib contusion. The rib is bruised, a small haemorrhage occurs under its periosteum and the condition is very painful.
- One or more ribs may be fractured by injury. Each rib may break at a single point along its length (***single rib fractures***), or may break at two or more places (***double rib fractures***). In the latter case, the chest wall loses its stability as part of the wall becomes mobile (***flail chest***). This can result in considerable respiratory problems.
- A special type of rib injury is commonly seen in car accidents in which the driver is violently thrown against the steering wheel (Steering wheel injury). Fractures take place at the anterior ends of ribs on either side of the sternum. The sternum itself is frequently fractured near its upper end. In such injuries, again, a portion of the chest wall including the sternum becomes mobile. The heart that lies immediately posterior to the sternum may be severely contused.
- Injuries to ribs can lead to pneumothorax, haemothorax, injury to lungs and to surgical emphysema.

Sternal Puncture

This is a procedure in which specimens of bone marrow can be obtained by passing a cannula into the manubrium sterni. Examination of bone marrow is useful in diagnoses of anaemiae, leukaemiae, and other diseases.

Surgical Approaches

For operations on the heart, the sternum is split into two by a cut in the midline. The two halves are retracted. After the operation, the two halves are stitched together. **Rib excisions** are common in thoracic surgeries. A longitudinal incision is made on the outer surface of rib and the required segment of the rib removed. A second longitudinal incision is then made through the inner covering of periosteum. Postoperatively, the rib regenerates from the osteogenetic layer of the periosteum.

Multiple Choice Questions

1. The vertebral arch of a typical vertebra is made up of:
   a. Right and left pedicles and right and left laminae
   b. Right and left pedicles and spinous process
   c. Right and left laminae and spinous process
   d. Right and left pedicles, right and left laminae and spinous process
2. With regard to the demifacets in atypical thoracic vertebra:
   a. The upper facet articulates with the vertebra's own rib
   b. Costal articulations with them are highly variable
   c. The lower facet is invariably on the pedicle
   d. The lower facet articulates with the vertebra's own rib
3. Episternum is the other name given to:
   a. Whole sternum
   b. Manubrium
   c. Corpus sterni
   d. Xiphi sternum
4. Manubriocostal joint of the first rib is:
   a. Synchondrosis
   b. Syndesmosis
   c. Synovial plane
   d. Synovial saddle
5. With regard to a typical rib:
   a. The neck is behind the transverse process of the preceding rib
   b. The lower border of the shaft is rounded to accommodate the costal groove
   c. The tubercle gives attachment to lateral costotransverse ligament
   d. The upper border of the shaft does not receive the external intercostal muscle

ANSWERS

1. a **2.** a **3.** b **4.** a **5.** c

Clinical Problem-solving

Case Study 1: In the labour room, you find a child being born with no sternum and the heart seen under thin membranes.

- What is the condition called?
- What structures are absent/missing in such a condition?
- Can you enumerate a similar condition in the abdomino-pelvic region?

Case Study 2: A friend of yours comes to you saying he has cervical rib.

- What is a cervical rib?
- What problems and symptoms would you anticipate in him?
- When does a normal first rib behave like a cervical rib?

(For solutions see Appendix).

Chapter 4

Joints of Thorax

Frequently Asked Questions

- Write notes on: (a) Intervertebral disc, (b) Costotransverse articulation, (c) Ligamentum flavum, (d) Pigeon chest.
- Write notes on: (a) Sternocostal joint, (b) Movements of the thoracic cage, (c) Bucket handle movement.
- Write notes on: (a) Manubriosternal joint, (b) Zygapophyses, (c) Barrel chest.

When an articulated thoracic cage is studied, it can well be seen that there are several joints between various bones; these joints collectively contribute to the formation of the thoracic cage itself. The joints which can conveniently be called the ***'joints of thorax'*** thus include:

- ***Intervertebral joints*** connecting adjacent thoracic vertebrae;
- ***Sternal joints*** between different parts of the sternum;
- ***Costovertebral joints*** between ribs and vertebrae;
- ***Costochondral joints*** between ribs and costal cartilages;
- ***Sternocostal joints*** or ***chondrosternal joints*** between costal cartilages and the sternum and
- ***Interchondral joints*** amongst the lower costal cartilages.

INTERVERTEBRAL JOINTS

Adjoining vertebrae are connected to one another through three main joints—(1) a median joint between the vertebral bodies; and (2) two joints (right and left) between the articular processes. Apart from the joints, the bodies, laminae, transverse processes and spinous processes of the adjoining vertebrae are also united by a number of ligaments, which together contribute to an additional syndesmosis.

Joints between Vertebral Bodies (Symphysial Joints)

Each vertebra has a body that is shaped roughly like a short cylinder. The body has more or less flat upper and lower surfaces. The inferior surface of the body of one vertebra articulates with the inferior surface of the body of the next vertebra.

The structure of a joint between any two vertebral bodies corresponds to that of a typical symphysis. The bony surfaces forming the joint are covered by thin layers of hyaline cartilage. The two plates of ***hyaline cartilage*** are united to each other by a thick ***intervertebral disc*** (Fig. 4.1), which is a plate of fibrocartilage. There is no joint cavity.

The ***vertebral bodies*** are further united by the anterior and posterior longitudinal ligaments, which, in effect

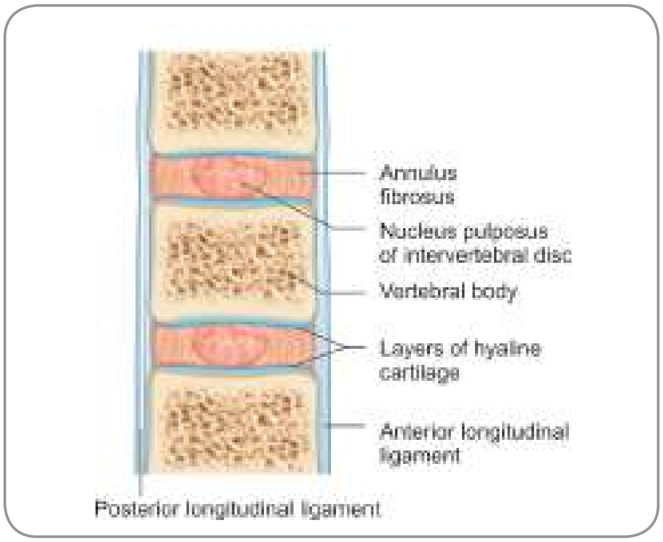


Fig. 4.1: Schematic sagittal section across vertebral bodies and intervertebral discs

are long ligaments extending from the sacrum to the base of skull. The anterior ligament is attached to the intervertebral discs and adjacent borders of the vertebral bodies anteriorly. The posterior ligament is attached similarly on the posterior aspect and within the vertebral canal.

Intervertebral Discs

Intervertebral discs are the chief bonds of union between adjoining vertebrae, thus making for symphysial joints. Each disc consists of an outer part called the ***annulus fibrosus*** and an inner part known as the ***nucleus pulposus***. The superficial part of the annulus fibrosus is made up more of collagen fibres but the deeper part is fibrocartilage. The fibres in the annulus are concentric; further, the fibres in alternate layers criss-cross, thus adding to strength. The nucleus pulposus is a fibro-gelatinous pulp and acts as a cushion or a shock-absorber (Fig. 4.1).

Joints between Vertebral Articular Processes

Each vertebra has four articular processes (or zygapophyses; Greek.zygon=yoke, apophysis=offshoot; yoke-like or H-shaped projections): right superior, left superior, right inferior and left inferior. Each process bears an articular facet. The inferior articular facets of one vertebra articulate with the superior articular facets of the next lower vertebra forming a series of ***zygapophyseal joints***. These are synovial joints having a joint cavity enclosed in a capsule. In the thoracic region, the articular facets are flat and the joints are, therefore, of the plane variety.

Ligaments Connecting Adjacent Vertebrae (Fig. 4.2)

Adjoining vertebrae are connected by numerous ligaments. Each such union can be regarded as a fibrous joint (syndesmosis); the various fibrous joints of a vertebra are collectively called the ***vertebral syndesmoses***. The ligaments are:

- ***Anterior longitudinal ligament***, passing from the anterior surface of the body of one vertebra to that of another.
- ***Posterior longitudinal ligament***, passing from the posterior surface of the body of one vertebra to that of another.

Corresponding portions of these ligaments also form ligaments of the corresponding vertebral body symphysis.

- ***Intertransverse ligaments***, interconnect adjacent transverse processes; these are, however, weak.
- ***Interspinous ligaments***, connect adjacent borders of spinous processes and are weak.
- ***Supraspinous ligaments***, connect the tips of spinous processes and are strong.

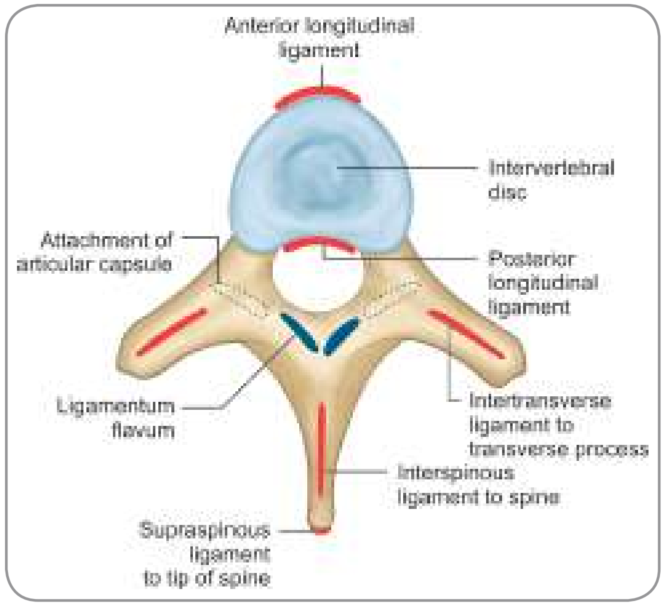


Fig. 4.2: Scheme to show ligaments connecting adjacent vertebrae

All these ligaments are predominantly made up of collagen fibres. They limit undue movement of vertebrae on one another.

- The ***ligamenta flava*** (otherwise called ***yellow ligaments***; Latin.flavus=yellow) pass from the lower border of the lamina of one vertebra to the upper border of the lamina of the next lower vertebra. Medially, the right and left ligaments almost meet in the midline and, laterally, they extend upto the joints between the articular processes. They are made up of elastic tissue. They act as brakes preventing undue separation of laminae during flexion of the vertebral column. Their elasticity helps in straightening the vertebral column after flexion. By limiting movements, they also protect intervertebral discs from undue compression and consequent injury.

Movements of the Thoracic Vertebral Column

Movements between adjacent vertebrae take place simultaneously at all the three main joints (symphysis and synovial) and the additional syndesmosis connecting them. The range of movement permitted between any two vertebrae is slight. However, when the movements between various vertebrae get added together, the total movement becomes considerable.

Of the various possible movements, flexion, extension and lateral flexion are restricted in the thoracic region. Lack of flexibility is essential for maintaining the stability of the thoracic vertebral column, which, in turn, is essential for respiratory movements.

Rotational movements are more in the thorax when compared to the cervical and lumbar regions; they are greater in the upper thoracic region, and greatest in the lower thoracic region.

STERNAL JOINTS

It is already noted that the sternum consists of three parts—the ***manubrium***, the ***body*** and the ***xiphoid process***. All the three components are connected by joints.

Manubriosternal Joint

The lower end of the manubrium is attached to the ***body of the sternum*** at the manubriosternal joint (Fig. 4.3). This joint is a symphysis. The bony surfaces are covered by thin layers of hyaline cartilage which are connected to each other by fibrocartilage. The joint plays an important role in respiration, because it allows the body of sternum to move forward and backward in a hinge-like fashion.

The manubrium sterni and the body of sternum lie at an angle of about 163° to each other on the posterior (or internal) aspect thus providing an angulation of 17° on the external aspect of the thoracic cavity. This ***angulation*** (otherwise called the sternal angle or angle of Louis; named after the 18th century paris surgeon Antoine Louis) increases slightly during inspiration and becomes less in expiration (Fig. 4.3).

Xiphisternal Joint

This joint is also a symphysis, but the two bones generally undergo bony union by the age of 40 years.

Added Information

- The body of sternum is located at the vertebral levels T5 to T9.
- The lower part of xiphoid is located at the vertebral level T10.
- The xiphisternal joint lies at the level of lower part of T9. This point is the marker for the infrasternal angle, central tendon of diaphragm, lower limit of central part of thoracic cavity, inferior limit of heart and superior limit of liver.

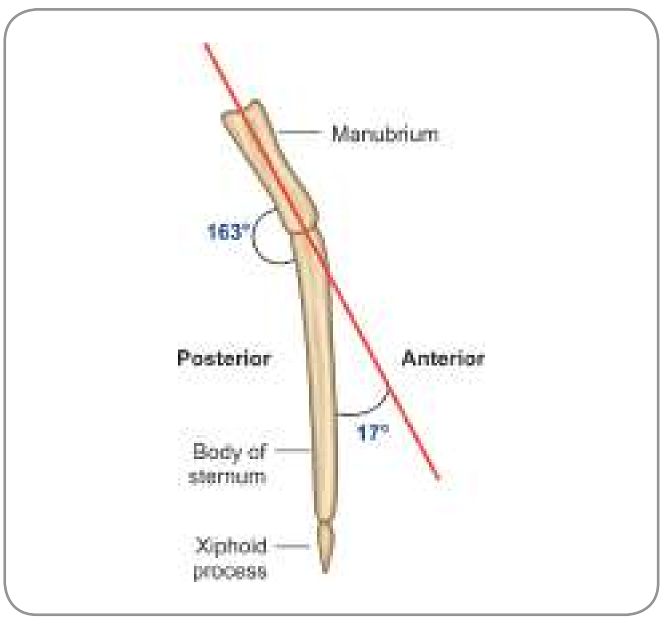


Fig. 4.3: Scheme to show angulation at the manubriosternal junction

JOINTS OF RIBS AND COSTAL CARTILAGES

Typically, a rib and its costal cartilage serve as a mechanism to connect the posteriorly placed vertebral column to the anteriorly placed sternum. The costae, therefore, articulate posteriorly with the vertebrae, thereby forming the ***costovertebral system*** and anteriorly with the sternum, thus forming the ***costosternal system***. In the case of the costovertebral system, there are two joints; the joint between the head of a rib and the sides of the bodies of vertebrae forming the ***costovertebral joint*** (Fig. 4.4) and the joint between the tubercle of the rib and the transverse process of the vertebra forming the ***costotransverse joint*** (Fig. 4.5). In the costosternal system, the costal cartilages articulate with the sternum either singly or through a common fusion. The 1st to the 7th costal cartilages articulate directly with the sternum forming the ***chondrosternal joints***.

Costovertebral Joints

These joints (also called capitular joints or ***costocorporeal joints;*** Latin.capitulum=head; Latin.corpus=body) unite the heads of ribs to the sides of the vertebral column. Semicircular facets (called the demifacets) are present on the sides of the body (near the upper and lower margins) of a typical thoracic vertebra. The head of each typical ***rib*** articulates with the demifacets of two adjacent vertebrae and with the ***intervertebral disc*** between these vertebrae (Fig. 4.4). Accordingly, the head of a rib is wedge-shaped with two sloping articular facets from the apex of the wedge.

- The apex of the wedge is called the ***crest of the head***; it is attached to the intervertebral disc by a transversely placed ***intra-articular ligament***;
- The lower facet articulates with the demifacet on the superior border of the body of the numerically corresponding vertebra (Fig. 3.8) (own vertebra);
- The upper facet articulates with the lower demifacet on the next higher vertebra;
- The ***intra-articular ligament*** divides the joint cavity into upper and lower separate parts.

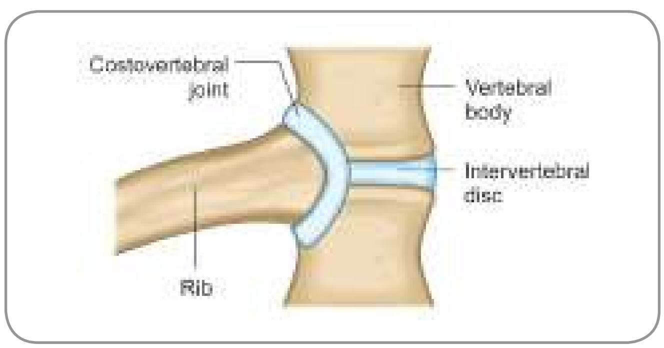


Fig. 4.4: Schematic coronal section across a costovertebral joint

The costovertebral joint is enclosed in a fibrous capsule that is strengthened in front by fibres which radiate from the head of the rib to the two vertebrae and to the intervertebral disc. These fibres constitute the ***radiate ligament*** (or triradiate ligament, since the radiating fibres are in three bundles—the intervertebral disc in the middle and the vertebrae above and below).

As the head of a rib articulates with two vertebrae, the joint is classified as ***compound***. As the joint cavity is divided into two parts, the joint can also be classified as ***complex*** (though the fibrous capsule is single, the synovial cavities are two).

Costovertebral joints of the 1st (many a time, the 10th), 11th and 12th ribs are atypical in that these ribs articulate only with the corresponding vertebrae. Hence, the heads of such ribs are rounded and there are no crests of heads and intra-articular ligaments.

Costotransverse Joints (Fig. 4.5)

These joints unite the tubercle of a rib to the tip of the ***transverse process*** of its own vertebra. A short distance lateral to the head, each rib bears a tubercle that is divisible into a medial articular part, and a lateral non-articular part. The medial part bears a facet that articulates with a facet on the front of the transverse process of the corresponding vertebra. The joint is synovial and has a fibrous capsule. The joint is also strengthened by a set of ligaments (Fig. 4.6).

The ligaments are:

- The ***lateral costotransverse ligament*** (Figs 4.6 and 4.7) that is attached laterally to the non-articular part of the tubercle of the rib and medially to the tip of the transverse process; it is otherwise called the ***ligament of the tubercle***;
- The ***superior costotransverse ligament*** (Fig. 4.7) that passes from the upper border of the neck of rib to the lower border of the transverse process of the ***next higher vertebra***; the ligament has anterior and posterior laminae; laterally, the anterior lamina blends with the internal intercostal membrane, and the posterior lamina blends with the external intercostal muscle.
- The ***costotransverse ligament*** (or the inferior or medial costotransverse ligament) that passes from the posterior surface of the neck of rib to the front of the transverse process of the ***corresponding vertebra***; it is otherwise called the ***ligament of the neck***.

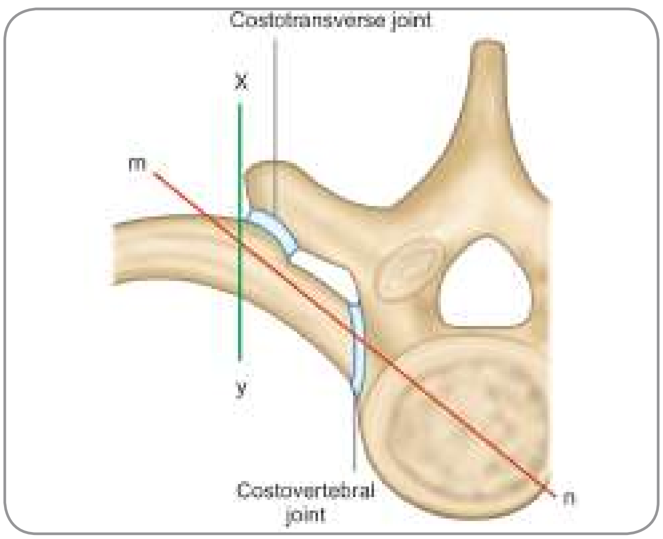


Fig. 4.5: Schematic section across the posterior part of a rib to show costovertebral and costotransverse joints

Key: x-y. Anteroposterior axis (that runs through the posterior and anterior ends of the rib) around which bucket handle rotation occurs **m-n:** Transverse axis (that runs longitudinally through the head and neck of rib) around which pump handle rotation occurs

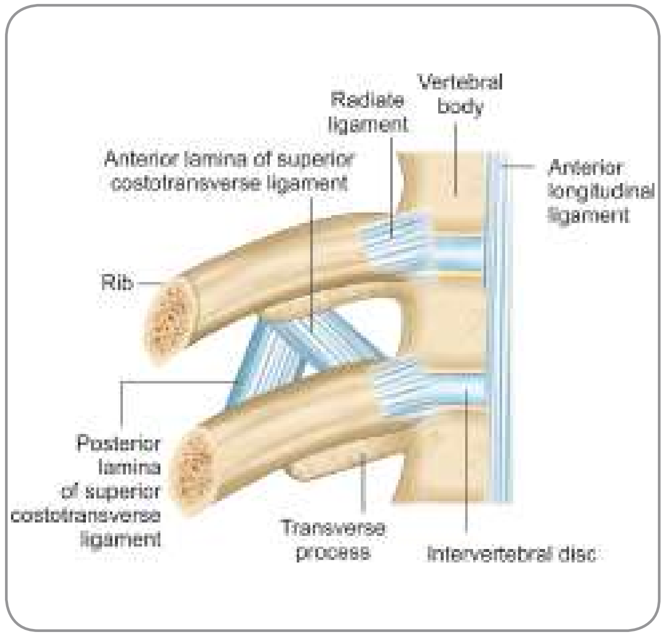


Fig. 4.6: Ligaments of costovertebral and costotransverse joints seen from the front

Costochondral Joints

These are joints within the costae. The anterior end of each rib bears a depression into which the rounded end of a costal cartilage is fixed. The two are held in position by continuity of the periosteum of the rib with the perichondrium of the cartilage. Truly, the costal cartilages are unossified extensions of the ribs; together the ribs and the costal cartilages form the costae.

Sternocostal Joints

These joints unite the medial ends of the 1st to 7th costal cartilages to the sides of sternum. They are also referred to as the chondrosternal joints.

The joint of the first costal cartilage with the manubrium sterni has customarily been described as a synchondrosis.

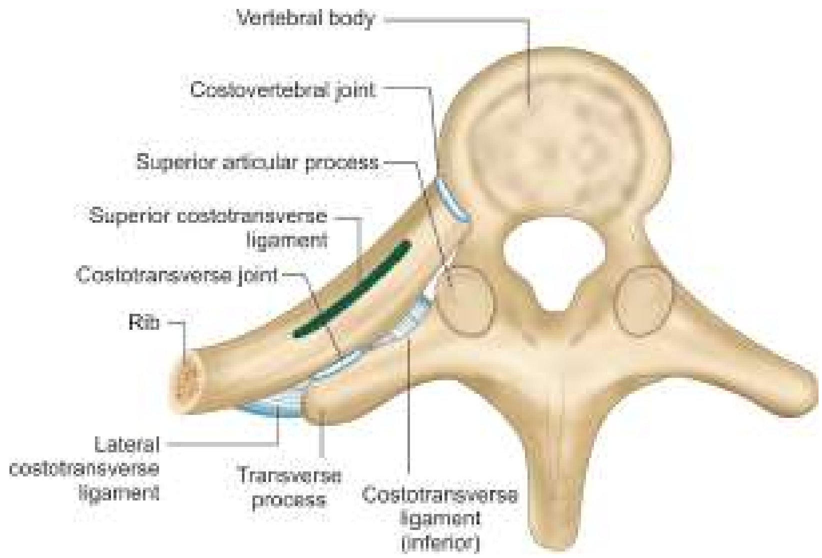


Fig. 4.7: Costotransverse joint and related ligaments

However, this costal cartilage is usually united to the manubrium through a plate of ***fibrocartilage*** and thus is not a typical synchondrosis.

The joints between 2nd and 7th costal cartilages on one hand and the sternum on the other are synovial joints. They are held together by the continuity of perichondrium and periosteum. They are also strengthened anteriorly and posteriorly by fibres which radiate from the costal cartilage to the sternum (often called the ***anterior*** and the ***posterior radiate ligaments***).

The 2nd costal cartilage articulates with the side of the manubrium and the first sternebra; the 6th with the side of the fourth sternebra and the 7th between the fourth sternebra and the xiphoid.

Interchondral Joints

The 6th to 9th costal cartilages come into contact with one another and form a number of small interchondral synovial joints. There are cavities usually between the 6th and 7th and the 7th and 8th and very often between the 8th and 9th costal cartilages. A synovial cavity may also be seen between the 5th and the 6th cartilages. The interjoint between the 9th and 10th cartilages is regularly fibrous and has no cavity.

Costae in situ

If the costae (ribs and costal cartilages) are studied (in position) in an articulated thoracic cage, several features of functional importance can be noticed.

- Each costa is arched; the rib portion takes a downward slope and the cartilage portion takes an upward slope. Such an arch pattern is true to all ribs from the 3rd to the 10th.
- The cartilages of the 1st, 11th and 12th costae continue the downward slope of their ribs. The cartilage of the 2nd costa is more or less horizontal.
- The sternal end of each costa is at a lower level than the vertebral end.
- The middle of each arch is at a lower level than a straight line joining the two ends.
- The length of the ribs and the cartilages increases progressively from the 1st to the 7th; the 7th rib is the longest; so also the 7th costal cartilage.
- The 8th rib has the greatest lateral projection; hence, the transverse diameter of the thorax increases progressively from the 1st to the 8th.
- The ribs increase in their obliquity from the 1st to the 9th. The 9th rib is the most obliquely placed.
- The anterior ends of the 11th and 12th ribs are tapering since they are not subjected to any terminal pressure.

Added Information

- The thickness of the intervertebral discs varies in different parts of the vertebral column. In the thoracic region, they are flat; they are very thin in the upper thoracic region, where movement is extremely restricted;
- In the young, the nucleus pulposus is soft and gelatinous, but this material is gradually replaced by fibrocartilage. When this happens, the nucleus pulposus merges with the annulus fibrosus.
- The intervertebral discs are very strong in the young. With advancing age, however, the annulus fibrosus becomes weak and it then becomes possible for the nucleus pulposus to burst through it. This is called ***prolapse of the disc*** (though it is really prolapse of the nucleus pulposus).

contd...

Added Information *contd...*

- Generally, bony ends taking part in any symphysis do not undergo bony union. However, the manubriosternal symphysis is atypical, bony union (manubriosternal synostosis) between the two bones taking place in many individuals after the age of 30.
- The articular facet on the tubercle of each vertebrosternal rib (true rib) is olive-shaped and fits well into the concave facet on the front of the ***transverse process***. Such a configuration allows rotation at the joint. The articular facet on the tubercle of a false rib lies closer to the lower border and, hence, is flat and oblique. The corresponding facet on the front of the transverse process is closer to its upper border allowing a sliding movement.
- ***Posterior angles of the ribs:*** Iliocostalis, a muscle of the lateral column of the muscles of the back, inserts through tendinous slips to the posterior aspects of the outer surfaces of the ribs. This produces an oblique marking on the backward projecting part of the outer surface. Anterior to this, the ribs are twisted downward, forward and medially. This point of twisting is called the ***angle (or posterior angle) of the rib***.
- The deep muscles of the back, including the iliocostalis, diminish in their size and bulk as they ascend. So, the angles of the ribs become progressively nearer the tubercles from below upward. At the level of the first rib, the angle and the tubercle coincide with each other.
- Ribs 1, 2, 11 and 12 have rough impressions for iliocostalis; but do not have a true twisting. Hence, these ribs have no true angles.
- At the sites of attachment of the external oblique of the abdomen to the lower eight ribs, the ribs are bent slightly backward, thus flattening the thorax marginally. These sites mark the anterior angles of the ribs and are best noticed in the middle four ribs (5, 6, 7 and 8).
- A vertebrosternal costa (a true rib and its cartilage) is described as a ***bucket handle***. Like a bucket handle, the two ends will have to articulate in similar fashion. Though the ribs 1 to 7 are vertebrosternal, the bucket handle fashioning of articulation is best developed in the 2nd, 3rd and rarely the 4th ribs. Like the head of the rib, the sternal end of the cartilage is also wedge-shaped with sloping articular facets; the socket is formed by the demifacets of the adjoining sternebrae; the joint cavity is divided by an intra-articular ligament running from the crest of the wedge to the junction of the vertebrae; the joint capsule has a ligament that radiates from the costal cartilage to the sternum on the ventral aspect.

MOVEMENTS OF RIBS

The movements taking place at the joints of the thorax allow for rhythmic expansion and contraction of the thoracic wall during respiration. Though the precise nature of all movements is complex and differs in different ribs, two fundamental movement patterns can be noticed:

- ***Pump handle pattern:*** The anterior ends of the ribs can move up or down by rotation at the costovertebral and costotransverse joints. The axis of rotation is transverse.

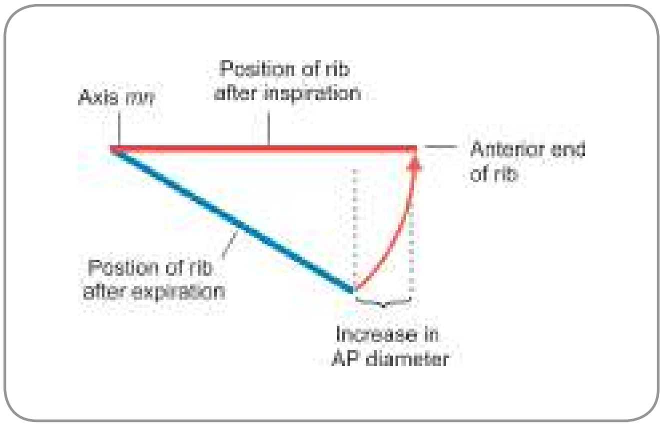


Fig. 4.8: Scheme to show how elevation of the anterior end of a rib during inspiration increases the anteroposterior diameter (AP) of the thorax—axis mn shown in Fig. 4.5

  - In expiration, the anterior ends of the ribs are lower than their posterior ends.
  - During inspiration, the anterior end moves upwards in an arc becoming more horizontal. This increases the ***anteroposterior diameter*** (Fig. 4.8) of the thorax.
  - The forward movement of the rib is made possible by an angular movement at the manubriosternal joint.
  - Movements of the sternum are comparable to those of a ***pump handle***; during inspiration, the sternum moves forward and upward; during expiration, it moves backward and downward.
  - Rotational movements leading to a pump handle pattern take place mainly in relation to the upper six ribs. These movements are facilitated by the fact that the articular surfaces on the tubercles of these ribs are convex.
- ***Bucket handle pattern:*** The second movement of the ribs occurs around an axis that is anteroposterior. The axis passes through the costotransverse and sternocostal joints.
  - In expiration, the middle of the rib is lower than its ends.
  - In inspiration, it is raised (like a bucket handle). This increases the ***transverse diameter*** (Fig. 4.9) of the thorax.
  - These movements take place mainly in the 7th to 10th ribs. The articular surfaces on the tubercles of these ribs are flat.

During ***quiet breathing***, movements of the ribs are produced by ***intercostal muscles***. Elevation (during inspiration) is produced by the external intercostals and depression (during expiration) by the internal intercostals, aided by elastic recoil of the thoracic wall (The intercostal muscles also make the region of the intercostal spaces stiff, thus resisting atmospheric pressure imposed on them because of negative intrapleural pressure).

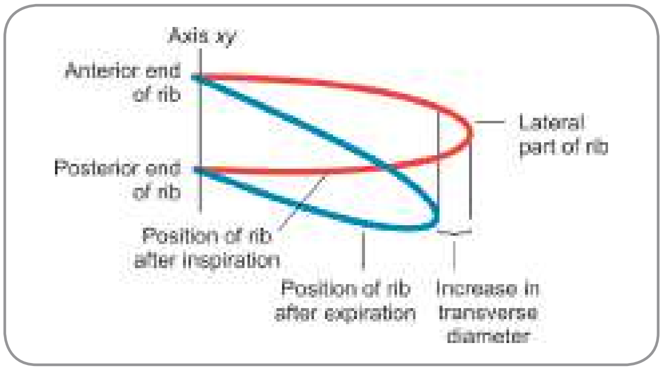


Fig. 4.9: Scheme to show how elevation of the side of a rib increases the transverse diameter of the thorax—axis xy shown in Fig. 4.5

In ***deep inspiration***, movements of the ribs are aided by contraction of other muscles attached to the ribs. The ***scalenii*** (present in the neck) and the ***sternocleidomastoid*** muscles elevate the first rib, while the erector spinae help in expansion of the thorax by reducing the concavity of the thoracic part of the vertebral column. In ***forced inspiration*** (against resistance), the scapulae are elevated and fixed by the trapezius, the levator scapulae and the rhomboideus muscles. With the arms fixed (by holding onto a firm object), contraction of the serratus anterior and of the pectoralis major pulls upon the ribs, thus helping in expansion of the thorax. In forced expiration (as in patients with asthma), the thorax is compressed by the latissimus dorsi and the abdominal muscles. The diaphragm also plays a very important role in respiration.

Clinical Correlation

Variations in Shape of the Thorax

In the normal adult, the thorax is more or less oval in transverse section. In infants, the thorax is more nearly circular as a result of which respiration is mostly abdominal.

In a condition called ***emphysema***, the lungs are dilated, and as a result the thorax can become rounded in section (***barrel chest***), making respiration much less effective.

Deformities seen in the thoracic cage may be congenital or may result from disease. In ***funnel chest***, the front of the chest (in the region of the body of sternum and xiphoid process) is depressed. As a result, the costal cartilages are curved inwards near their anterior ends. (In this condition, the basic defect is that the central tendon of the diaphragm is abnormally short so that the ***xiphoid process*** is pulled inwards). In ***pigeon chest***, the thorax may project forward in midline (as is normal in birds and so the name). These deformities can be surgically corrected.

Deformities may involve the thoracic spine. The spine may be bent forward (***kyphosis***) or to one side (***scoliosis***). The two may be combined (***kyphoscoliosis***).

Multiple Choice Questions

1. The joint between two vertebral bodies is a:
- a. Symphysial joint
- b. Synovial joint
- c. Synovial joint with no cavity
- d. Fibrous joint

2. Ligamentum flavum connects:
- a. The laminae of adjacent vertebrae
- b. The transverse processes of same vertebra
- c. The pedicles of adjacent vertebrae
- d. The spines of adjacent vertebrae

3. Intra-articular ligament connects:
- a. Head of a rib and the intervertebral disc
- b. Head of a rib and the transverse process
- c. Head of a rib and the vertebral body
- d. Head of a rib and the lower demifacet

4. Movements of sternum during respiration are comparable to:
- a. Bucket handle
- b. Pulley
- c. Pump handle
- d. Piston

5. Kyphosis is:
- a. Right sideward bend
- b. Left sideward bend
- c. Forward bend
- d. Backward bend

ANSWERS

1. a **2.** a **3.** a **4.** c **5.** c

Clinical Problem-solving

Case Study 1: A 45-year-old man is suffering from disc prolapse.
- What do you understand by this term?
- What is the reason for this condition to occur?
- What are the symptoms of this condition?

Case Study 2: When you examine the chest X-ray of a male patient, you find his manubriosternal joint is completely united by bone.
- Is this a common/normal finding?
- If so, which age group shows such changes?
- What type of joint is the manubriosternal joint and why so?

(For solutions see Appendix).

Chapter 5

Walls of Thorax

Frequently Asked Questions

- Give a detailed account of the intercostal muscles.
- Write notes on: (a) Anterior intercostal artery, (b) Posterior intercostal artery, (c) Azygos vein, (d) Typical intercostal nerve.
- Discuss the diaphragm in detail and enumerate the various structures passing through its apertures.

The thoracic wall surrounds the thoracic cavity. Skin and soft tissue cover the musculoskeletal frame of the thoracic wall. However, skin and soft tissue over the anterolateral aspects of the thoracic cage alone are considered as part of thoracic wall. The same structures over the posterior aspect are included as part of 'the back region'. The pectoral region, though it overlies the chest wall, is included in the upper limb for functional reasons.

The thoracic skeleton is made of the osteocartilaginous thoracic cage. This includes the twelve thoracic vertebrae and their interposed intervertebral discs, the twelve pairs of ribs and their costal cartilages and the sternum. These have already been studied and we continue our study of the other structures which constitute the thoracic wall.

FASCIAE OF THORACIC WALL

The deep fascia overlying the pectoral muscles forms the ***pectoral fascia***. Deep to the pectoralis major muscle is another specialised layer of fascia called the ***clavipectoral fascia***. On the internal aspect, the thoracic cage is lined by a thin layer of loose connective tissue called the ***endothoracic fascia***. This fascia keeps the parietal pleura attached to the thoracic wall. Over the apices of lungs, the endothoracic fascia condenses to form the ***suprapleural membrane***.

MUSCLES OF THORACIC WALL

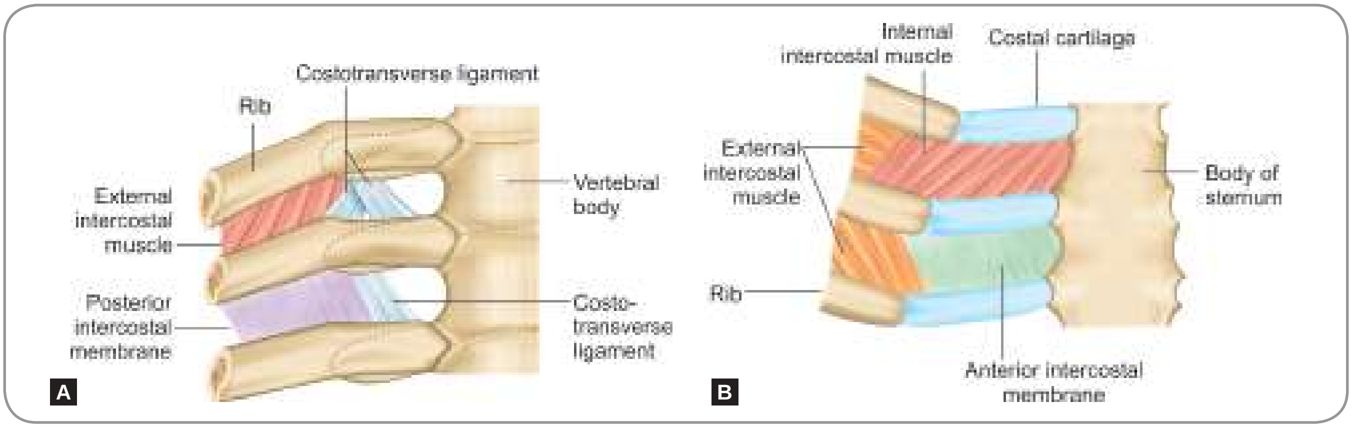
The muscles covering the thoracic cavity can broadly be classified into extrinsic and intrinsic muscles. The extrinsic muscles connect the thoracic wall to other regions like upper limb and vertebral column. These include the trapezius, latissimus dorsi, rhomboidus major and minor, levator scapulae, pectoralis major and minor, serratus anterior, subclavius, supraspinatus, infraspinatus, teres major and minor and the scalene muscles. The intrinsic muscles are the true muscles of the thoracic wall and are the intercostals, the subcostals, the transversus thoracis, the levatores costarum and the serratus posterior. They fill up the gap between the ribs (intercostal spaces) along with the intercostal nerves, vessels and lymphatics.

Intercostal Spaces

There are eleven intercostal spaces between the twelve ribs on either side posteriorly. Anteriorly, only nine intercostal spaces are present as the last two ribs are floating in nature and lack the anterior attachment. Each intercostal space extends, posteriorly, to the superior costotransverse ligaments (extending between the neck of the rib and the transverse process of the vertebra above it) and anteriorly, to the sternum.

Intercostal Muscles (Fig. 5.1 and Table 5.1)

- The ***intercostal muscles*** fill the intervals between adjacent ribs. They are arranged in three layers—***external, internal*** and ***innermost***. There are eleven pairs of external and internal intercostal muscles. The innermost layer is often deficient in the upper intercostal spaces (Figs 5.1A and B).
- The external intercostals reach the costotransverse ligaments posteriorly, but are deficient in front. They



Figs 5.1A and B: A. Posterior ends of two intercostal spaces viewed from within the thorax—the internal intercostal membrane has been removed in the upper space to reveal the underlying external intercostal muscle **B.** Anterior ends of two intercostal spaces viewed from the front—The external intercostal muscle and membrane have been removed in the upper space

Table 5.1: Intercostal muscles and sternocostalis

Muscle	Origin	Insertion	Direction of fibres	Action
External intercostal	Lower border of rib above	Upper border of rib below	Obliquely from one rib to another, the upper attachment being nearer to the vertebral end and the lower attachment being nearer to the sternal end of intercostal space	Prevent the thoracic wall from bulging inwards or outwards as a result of pressure changes during inspiration and expiration
Internal intercostal	Floor of the costal groove of rib above	Upper border of rib below	At right angles to external intercostal. On the front of the thorax fibres run downwards and laterally	
Innermost intercostal	Upper lip of the costal groove of the rib above	Inner lip of the upper border of the rib below		
Subcostales	Inner surface of rib near angle	Inner surface of rib two or three intercostal spaces below origin (Fig. 5.2)		
Sternocostalis/ Transversus thoracis/ triangularis sternae	Posterior aspect of: • Lower 1/3rd of body of sternum • Xiphoid process. • Costal cartilages (adjoining parts of 4th to 7th)	Lower borders and inner surfaces of the 2nd, 3rd, 4th, 5th and 6th costal cartilages (Fig. 5.3)	• Upwards and laterally from origin to insertion • Lowest fibres are transverse	Depresses costal cartilages into which it is inserted

Nerve Supply: All muscles described in this table are supplied by intercostal nerves of spaces concerned.

stop short at the level of the costochondral junctions. Between the costal cartilages, they are replaced by the ***external intercostal membranes.*** The muscle fibres run anteroinferiorly from the upper rib to the lower rib. These muscles become continuous inferiorly with the external oblique muscles of the anterior abdominal wall.

- The internal intercostal muscles do not extend over the entire length of the space—anteriorly they extend right up to the sternum, but posteriorly they end at the level of the angles of the ribs beyond which they are replaced by the ***internal intercostal membranes.*** They lie deep to the external intercostal muscles and the fibres are at right angles to those of the latter. The muscle fibres run posteroinferiorly from the upper rib to the lower rib. These muscles become continuous inferiorly with the internal oblique muscles of the anterior abdominal wall.

The innermost layer is made up of three distinct muscles as follows:

1. The ***intercostalis intimus*** (or the ***innermost intercostal muscle***) is seen only in the middle two-fourths of the intercostal space; it can be considered the deeper part of the internal intercostals and is separated from the latter by intercostal nerves and vessels.

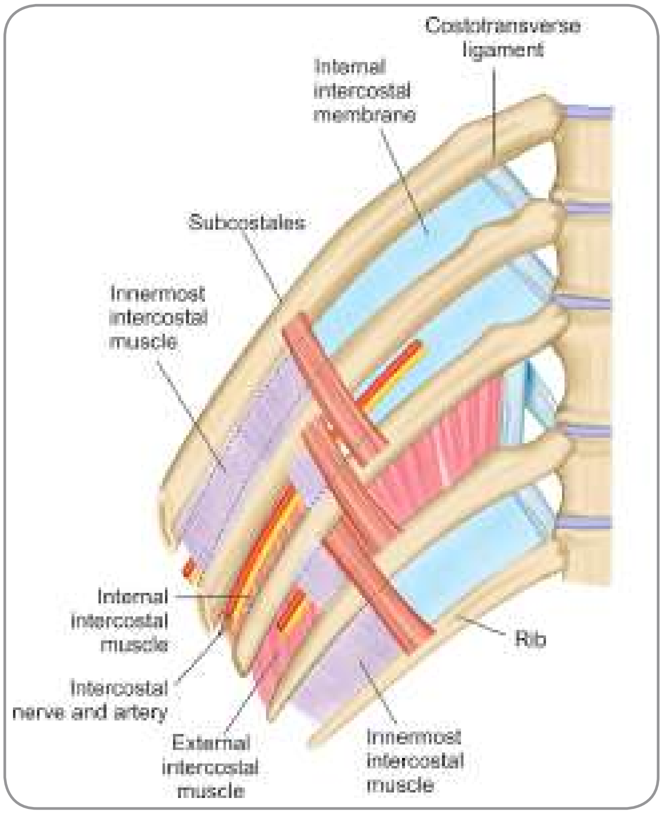


Fig. 5.2: Diagram of the posterior ends of some intercostal spaces (internal aspect) to show the subcostales. Some layers have been removed from the 2nd and 3rd spaces drawn

2. The ***subcostal muscles*** are present only over the posterior part of the intercostal space (near the angles of the ribs); they are usually well developed only in the lower thoracic wall and extend from the inner surface of a rib to the inner surface of the second or third rib below; their fibres follow the same direction as that of the internal intercostals and may merge with them (Table 5.1 and Fig. 5.2).
3. In the anterior part of the thoracic wall, the innermost layer is formed by the ***sternocostalis***; these are actually four or five muscular slips which run superolaterally from the sternum to the costal cartilages; they are continuous inferiorly with the transversus abdominis muscles of the anterior abdominal wall (Table 5.1 and Fig. 5.3).

All the three muscles of the inner layer lie in the same plane. Sometimes, they are collectively called the ***transversus thoracis,*** though this name is restricted by some authorities to the sternocostalis alone. The intercostal nerves and vessels run between the muscles of the second and the third layer. The intercostal muscles are lined on the inside by costal pleura.

Additional Notes on the Intercostal Muscles

The external and internal intercostal are active during inspiration and expiration respectively. However, their main role seems to be producing movements in the ribs during forced inspiration and expiration.

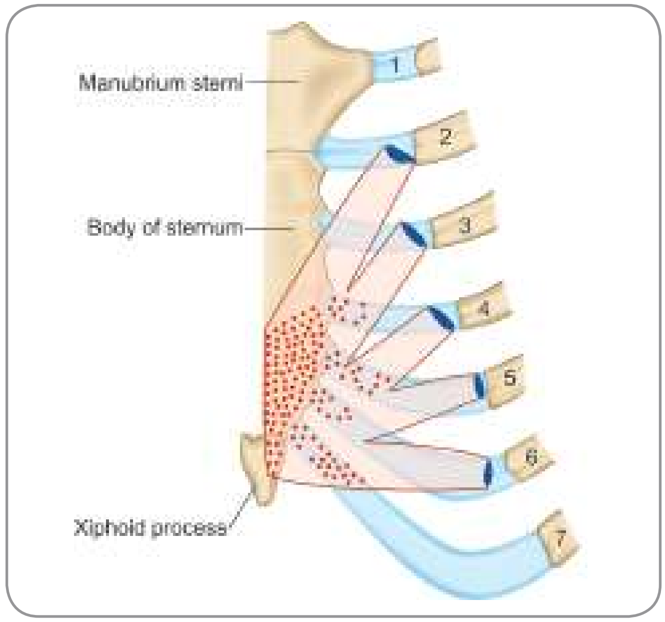


Fig. 5.3: Scheme to show attachments of sternocostalis

In addition to the muscles seen in relation to the intercostal spaces, other muscles which constitute the thoracic wall are present at the back, superficial to the thoracic cage.

Serratus Posterior Superior

This muscle is present on the back deep to the trapezius and rhomboideus muscles. It arises from the lower part of the ligamentum nuchae, spines of C7, T1, T2, T3 vertebrae and inserts into the upper border of 2nd, 3rd, 4th and 5th ribs just lateral to their angles.

Serratus Posterior Inferior

This muscle lies in the back, deep to the latissimus dorsi, and superficial to the thoracolumbar fascia at the junction of the thoracic and lumbar regions. It arises from the spines of the lower two thoracic and upper two/three lumbar vertebrae and inserts into the inferior borders of the lower four ribs lateral to their angles.

Levatores Costarum

The levatores costarum are a series of twelve small muscles placed on either side of the back of the thorax just lateral to the vertebral column. Each muscle arises from the tip of a transverse process, the highest from C7 and the lowest from T11. The fibres pass downwards and laterally to be inserted into rib next below. Some of the lower muscles of the series have additional fasciculi which gain attachment to the second rib below the transverse process of origin. These longer fasciculi are called the ***levatores costarum***

longi. In contrast, the other fasciculi constitute the ***levatores costarum breves.***

All muscles mentioned above are supplied by the dorsal rami of thoracic spinal nerves.

These muscles can elevate the ribs to which they are attached. However, they are probably of no functional importance in human beings. Recent studies indicate that the serratus posterior superior and inferior are primarily proprioceptive in nature and not motor. They are responsible for sending information about the position of the trunk.

Clinical Correlation

- ***Abscesses over intercostal spaces:***
  - ***Cold abscess:*** Cold abscesses may be seen in relation to intercostal spaces resulting from tuberculous infection of intercostal lymph nodes or of vertebrae. Pus from these sources can pass along intercostal nerves and vessels for considerable distances and may become superficial at sites where the lateral or anterior cutaneous branches emerge.
  - ***Empyema necessitans:*** An abscess over the thoracic wall can also be caused secondary to collection of pus in the pleural cavity (***empyema***). Pus may perforate the chest wall (and can do so along the track of a needle used for aspiration) and present as an abscess.
- ***Paracentesis thoracis:*** Fluid in the pleural cavity can be aspirated by passing a needle into an intercostal space (usually the 6th) in the midaxillary line. As the neurovascular bundle of each intercostal space lies along the upper border of the space, the needle has to be passed through the lower part of the space to avoid injury to them. The structures encountered during the aspiration are from outside inwards, skin, superficial fascia, the serratus anterior muscle, the intercostal muscles (three layers) and the parietal pleura.
- ***Thoracotomy:*** A procedure to gain access into the thoracic cavity by opening the chest wall is called thoracotomy. Depending upon the region to be approached, thoracotomy can be anterior, posterior or lateral. In this procedure, the periosteum covering a rib is incised and a suitable length of rib resected. An incision is then made into the periosteum lying deep to the rib thereby opening the pleural cavity for approach of the organs within it.

DIAPHRAGM

The diaphragm is a curved musculo-fibrous sheet that forms a partition between the cavities of the thorax and the abdomen. Its convex upper surface faces the thorax and its concave inferior surface is directed towards the abdomen.

Attachments of Diaphragm (Fig. 5.4)

Origin

The diaphragm has a more or less circular origin from the inferior thoracic aperture. The origin can be divided into sternal, costal and lumbar (vertebral) parts.

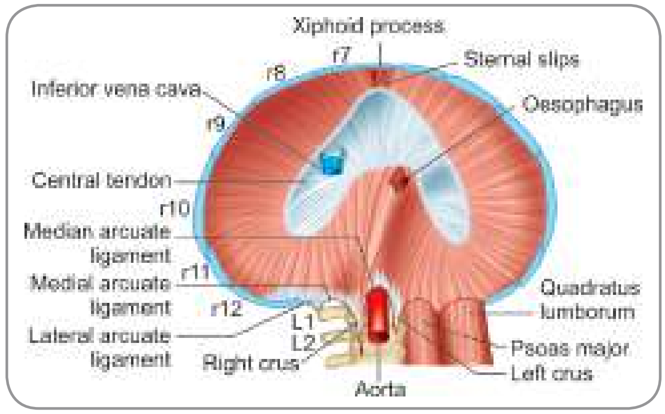


Fig. 5.4: Scheme to show attachments of the diaphragm

- The ***sternal part*** consists of two slips, right and left, which arise from the back of the xiphoid process.
- The ***costal part*** consists of broad slips, one from the inner surface of each of the lower six ribs (i.e., 7th–12th) and their costal cartilages. These slips interdigitate with those of the transversus abdominis (muscle of the abdominal wall).
- The ***lumbar (vertebral) part*** arises from two aponeurotic arches called the medial and lateral arcuate ligaments and from the anterolateral aspects of the bodies of lumbar vertebrae by two pillars or crura. The right crus is larger than the left. It arises from the bodies of vertebrae L1, L2, L3 and from the intervening intervertebral discs. The left crus arises similarly from vertebrae L1 and L2. The medial margins of the two crura are joined to each other (at the level of the lower border of vertebra T12) to form the ***median arcuate ligament.*** The descending aorta passes from thorax to abdomen under cover of this ligament.

The ***lateral arcuate ligament*** represents a thickened band of the fascia over the quadratus lumborum (muscle in the posterior wall of the abdomen). It is attached laterally to the twelfth rib (about its middle) and medially to the transverse process of the first lumbar vertebra.

The ***medial arcuate ligament*** is a thickened band of the fascia covering the psoas major. It is attached laterally to the transverse process of the first lumbar vertebra. Medially, it becomes continuous with the lateral margin of the corresponding crus and thus attached to the sides of the bodies of the lumbar vertebrae.

Insertion

From its extensive origin, the muscular fibres of the diaphragm run upwards and converge to be inserted on the margins of a large, flat, ***central tendon*** (Fig. 5.4) that is located just below the pericardium and heart. The central tendon is shaped like a trefoil leaf (trifoliate) presenting median, right and left leaflets which are fused together. The median ***(anterior) leaf is in the form of an equilateral***

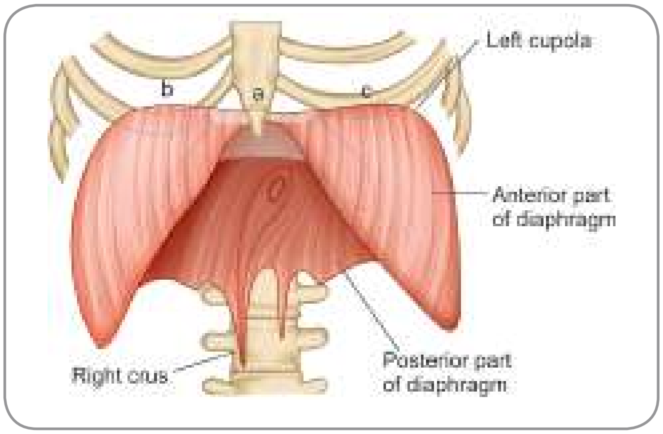


Fig. 5.5: Diaphragm as seen from the front

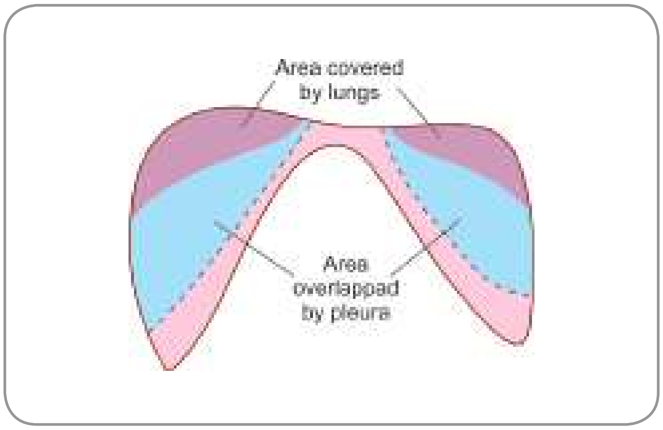


Fig. 5.6: Structures in front of the anterior part of the diaphragm

triangle with the apex directed towards the xiphoid process and base posteriorly; the base is continuous with the two tongue-shaped right and left leaves.

Dome of Diaphragm

The upper convex part of the diaphragm is called its ***dome***. The dome bulges considerably into the bony thorax.

- The central part of the dome ('*a*' in Fig. 5.5) is formed by the central tendon and lies at the level of the xiphisternal joint. It is placed somewhat lower than the right and left muscular convexities (or ***cupolae***).
- The right cupola ('*b*' in Fig. 5.5) is slightly higher than the left ('*c*' in Fig. 5.5) because of the presence of the liver below it.
- The level of the dome rises and falls with expiration and inspiration respectively.
- It is also influenced by posture; being highest when the body is supine, intermediate while standing and lowest while sitting.

The upper surface of the diaphragm is related to thoracic contents namely, the heart and pericardium in the middle and the lungs and pleurae on the sides. The lungs and pleurae descend in front, on the sides and behind the diaphragm (Fig. 5.6) into the space between it and the thoracic wall. The inferior surface of the diaphragm is related to abdominal contents.

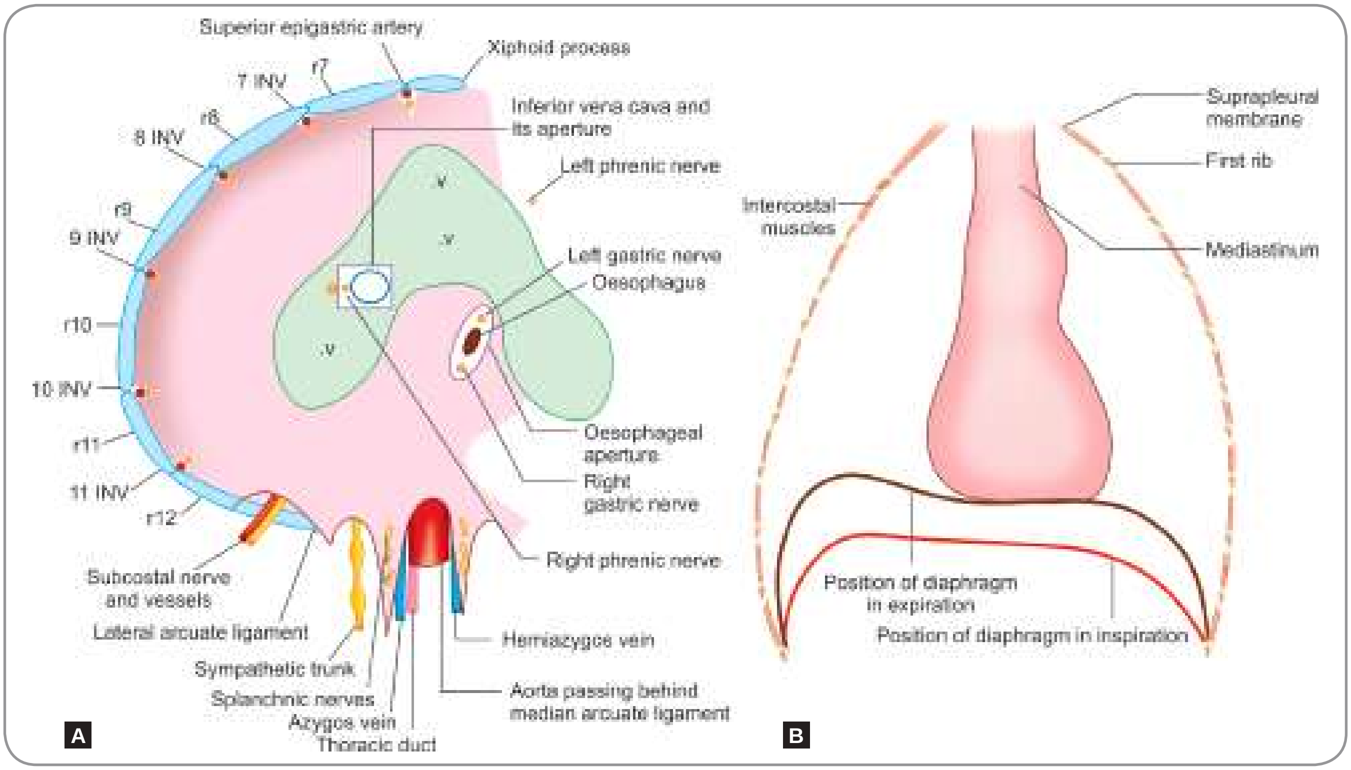
Apertures in Diaphragm

Structures passing from thorax to abdomen (or ***vice versa***) pass through apertures in (or around) the diaphragm. Some of the apertures are larger while some of them are much smaller.

Major Openings

There are three large apertures, one each for the aorta, the oesophagus and the inferior vena cava (Figs 5.7A and B).

- The ***aortic aperture (or aortic hiatus)*** is an osseo-aponeurotic opening and lies behind the median arcuate ligament, in front of the disc between vertebrae T12 and L1. The aorta, therefore, passes behind the diaphragm rather than through it. This is the lowest and most posterior of the three major openings.
  - During inspiration, the pull of muscular fibres on the median arcuate ligament ensures that the aorta is not compressed.
  - The aortic aperture also transmits the thoracic duct (which lies to the right side of the aorta) and sometimes the azygos and hemiazygos veins.
- The ***aperture for the oesophagus*** is elliptical in shape. It is situated at the level of the tenth thoracic vertebra. The opening is above, in front and to the left of the aortic aperture.
  - It is formed by splitting of the fibres of the right crus a little below their attachment to the central tendon.
  - Because the oesophagus is surrounded by muscle, it is compressed during expiration. This prevents regurgitation of the contents of the stomach.
  - The oesophageal aperture also transmits the right and left gastric nerves that are continuations of the vagus nerves. The left nerve is placed anteriorly and the right posteriorly. Oesophageal branches of the left gastric artery and some lymphatics also pass through the oesophageal aperture.
- The ***opening for the inferior vena cava*** lies in the central tendon at the level of the lower border of eighth thoracic vertebra. The opening is quadrilateral and aponeurotic. It is the highest of the three major openings and is located at the junction of the right leaf with the central area of the tendon.
  - The wall of the vena cava is adherent to the opening. This helps to expand the vessel during inspiration and facilitates venous return through the vessel.
  - The vena caval opening also transmits the whole or part of the right phrenic nerve.



Figs 5.7A and B: A. Schematic diagram to show apertures in the diaphragm. INV= Intercostal nerve and vessels; 7th to 12th ribs **B.** Diagram to show change in level of the diaphragm during inspiration and expiration

Minor Openings

Apart from the major openings, there are several minor openings through which number of structures pass between the thorax and abdomen.

- The left phrenic nerve passes through the muscular part of the diaphragm, to the left of the central tendon.
- Numerous small veins pass between the thorax and abdomen through small apertures in the central tendon.
- The ***superior epigastric artery*** (a terminal branch of the internal thoracic artery) passes through the gap between the slip from the xiphoid process and that from the seventh rib and costal cartilage (on either side).
- The ***musculophrenic artery*** (another terminal branch of the internal thoracic artery) passes through the interval between slips from the 7th and 8th ribs. This interval also transmits the 7th intercostal nerve and vessels.
- The ***8th*** to ***11th intercostal nerves and vessels*** pass through intervals between slips from the 8th and 9th ribs, 9th and 10th ribs, 10th and 11th ribs, and 11th and 12th ribs respectively.
- The ***subcostal nerves and vessels*** leave the thorax by passing behind the lateral arcuate ligament.
- The ***sympathetic trunk*** passes behind the medial arcuate ligament.
- The greater, lesser and least ***splanchnic nerves*** (arising from the sympathetic trunk) enter the abdomen by piercing the corresponding crus.
- When the azygos vein does not pass through the aortic opening, it may pass through the right crus, or behind it. The hemiazygos vein may have a similar relationship to the left crus.

Actions of Diaphragm

The diaphragm is the chief muscle of respiration, responsible for approximately two-thirds of quiet breathing in healthy humans. The main force for inspiration is provided by the diaphragm.

During inspiration, the lower ribs are fixed and contraction of the diaphragm draws the central tendon downwards increasing the vertical diameter of the thorax. The movement of the central tendon is limited by the resistance offered by the abdominal muscles and viscera. Once the movement of the central tendon is fixed by the abdominal viscera, it acts as a fixed point. With the continuing contraction of the diaphragm, the second to tenth ribs are elevated and the inferior portions of the ribs are turned outwards. This results in the elevation of the medial aspects of the ribs thereby increasing the transverse dimension of the chest. This movement is also called the ***bucket handle movement*** and is most evident in the lower ribs. Simultaneously, movements at the costovertebral joints cause elevation of the anterior ends of the ribs that push the body of sternum and the upper ribs forwards, thereby increasing the anteroposterior diameter of the chest. This is called the ***'pump handle movement'*** and is most evident in the upper ribs.

Acting along with the muscles of the anterior abdominal wall, the diaphragm helps to increase intra-abdominal pressure during acts like urination, defaecation or vomiting.

Acts requiring forcible expulsion of air from the lungs like sneezing or laughing are preceded by a deep inspiration (contraction of the diaphragm) followed by contraction of the expiratory muscles.

Nerve Supply

The diaphragm receives its motor supply through the phrenic nerves. The right crus of the diaphragm is innervated by both the right and left phrenic nerves as some of its fibres form part of the diaphragm to the left of the oesophageal opening. The left crus of the diaphragm is innervated by the left phrenic nerve only.

Sensory innervation to the central part of the diaphragm is by the phrenic nerves whereas the peripheral part of diaphragm is innervated by the lower six intercostal nerves in line with its development from both cervical myotomes and mesoderm of the body wall.

Clinical Correlation

The dome of the diaphragm is seen in skiagrams (radiographic pictures) of the chest. Normally the right dome is seen at a higher level than the left due to the presence of the liver on the right side. Movements of the diaphragm can also be visualised by fluoroscopy.

Diaphragmatic herniae: The diaphragm having a number of natural openings is prone to herniation of the abdominal contents through any of these openings either due to developmental or acquired reasons. The following are the various herniae which are seen in association with the diaphragm.

Congenital Diaphragmatic Herniae

Posterolateral hernia**:** The posterolateral hernia is one of the most common congenital diaphragmatic herniae in which the defect is seen in the posterolateral part of the dome in the region of eleventh or twelfth rib. This defect is also called the ***foramen of Bochdalek***. The hernia is more common on the left side. It has no sac, there being free communication between the pleural and peritoneal cavities. Herniation of abdominal contents into the thorax may produce severe respiratory distress soon after birth and requires immediate surgery to save the life of the infant.

Posterior hernia**:** It is caused by failure of development of the posterior part of the diaphragm where the gap lies in front of the vertebral column. The aorta and oesophagus lie in the gap. This hernia also does not have a sac.

Retrosternal hernia**:** An abnormally large gap, known as the ***foramen of Morgagni,*** may exist between the sternal and costal origins of the diaphragm. It is more common on the right side and is usually asymptomatic. The herniation, when occurs, is through the anterior part of the diaphragm and often contains part of the transverse colon.

Central diaphragmatic hernia**:** This occurs through one of the domes of the diaphragm, usually the left.

Eventration of the diaphragm**:** Strictly speaking this is not a diaphragmatic hernia, but it is convenient to consider it here. The term is applied to a condition in which part of the diaphragm is thin and aponeurotic and bulges abnormally upwards into the thorax.

Congenital hiatus hernia**:** Congenital hernia can also occur through a defective normal opening where it is called a congenital hiatus hernia. A congenital hernia, rarely, may occur through a wide oesophageal hiatus; however, most oesophageal hiatus herniae are acquired.

Acquired Hiatus Herniae

Three types of oesophageal hiatus herniae are commonly seen.

Sliding hiatus hernia**:** In this type the oesophagus is short. Therefore,the cardio-oesophageal junction (also referred to as the oesophago-gastric junction) and the adjoining part of the stomach pass through the hiatus and lie in the posterior mediastinum (Fig. 5.8), leading to loss of normal angulation between the oesophagus and the cardiac end of the stomach. Possibly as a result of this factor, the normal physiological sphincter here becomes ineffective leading to regurgitation of the acid contents of the stomach into the oesophagus resulting in inflammation and fibrosis. Fibrosis leads to further shortening of the oesophagus, in turn causing further pulling of the stomach into the thorax. Factors leading to this hernia are (a) Weakness of muscle around the oesophageal hiatus which often is a result of degeneration with age; (b) Increased intra-abdominal pressure due to any cause.

Paraoesophageal (or rolling) hiatus hernia**:** In this type, the oesophagus is of normal length and the cardio-oesophageal junction remains in the abdomen. But, a part of the stomach passes through the hiatus and lies within the posterior mediastinum parallel to the oesophagus (Fig. 5.9). As more and more of the stomach enters the thorax, the stomach appears to 'roll' on itself, the cardiac end becoming lower than the greater part of the stomach. However, as the cardio-oesophageal junction is normal, there is no reflux of gastric contents into the oesophagus.

Mixed hiatus hernia**:** This is a mixture of the two types described above (Fig. 5.10).

Treatment of hiatus hernia**:** Some patients of hiatus hernia can obtain relief with conservative treatment. For patients requiring surgical intervention, the cardio-oesophageal junction is surgically placed back into the abdomen, restoring its normal angulation. To prevent recurrence of the hernia, the procedure is accompanied by narrowing of the oesophageal hiatus.

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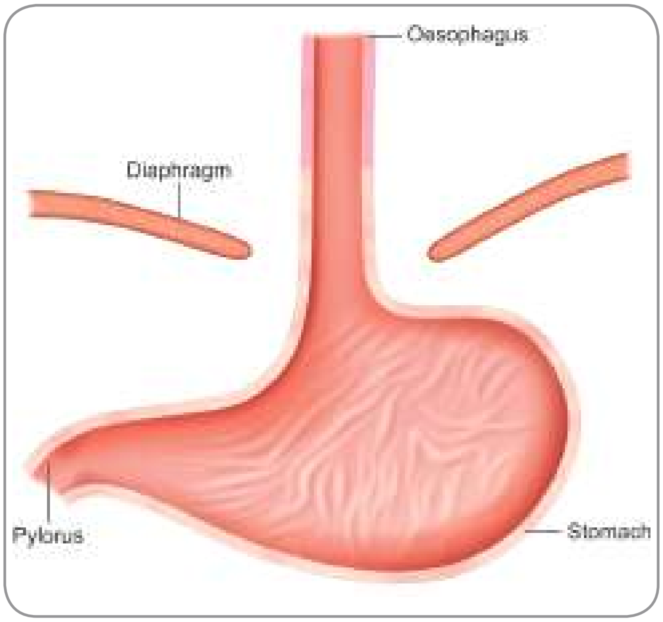


Fig. 5.8: Diagram showing a sliding hiatus hernia

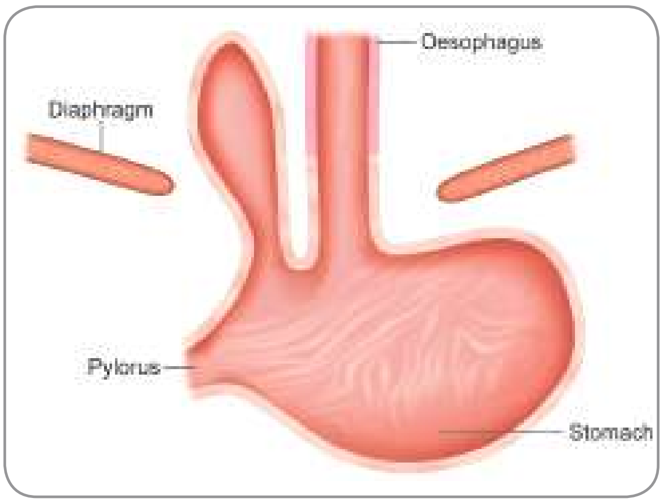


Fig. 5.10: Diagram to show a mixed type of hiatus hernia

Clinical Correlation ***contd…***

Rupture of diaphragm and traumatic hernia: The diaphragm may rupture following a bullet wound or a severe crushing injury. The stomach or colon may herniate through the opening created into the thorax.

Paralysis of one half of the diaphragm: Paralysis of one half of the diaphragm happens in injuries of phrenic nerve.

Normally, both domes of the diaphragm descend during inspiration. When one side is paralysed, that half cannot descend. On the contrary, pressure of abdominal viscera pushes it upwards. This is called paradoxical movement of the diaphragm which is best visualised by fluorescent radiography. Injury of the phrenic nerve can be iatrogenic (occurs during several thoracic surgeries).

Referred pain: Diaphragmatic pain is frequently felt at the tip of the shoulder, reflecting common nerve root origins in the neck. Pain is usually felt in inflammation of diaphragmatic pleura in conditions like basal pneumonia or pleural effusions.

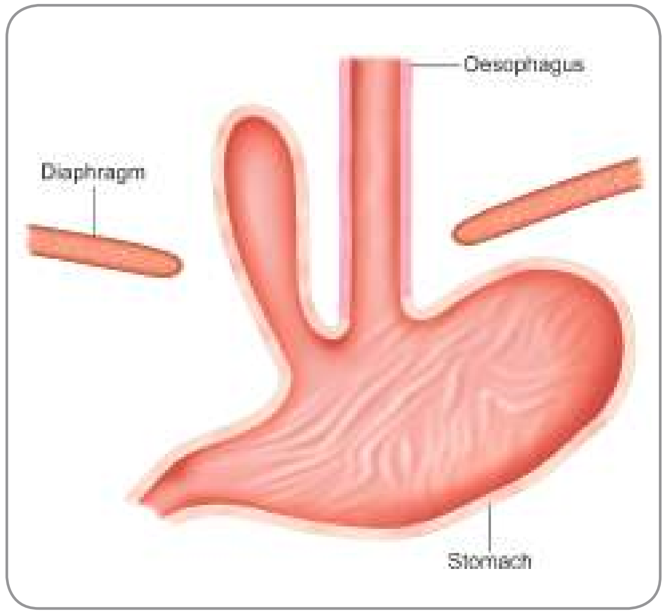


Fig. 5.9: Diagram showing a paraoesophageal hiatus hernia

ARTERIES OF THORACIC WALL

Muscles of the thoracic wall receive their blood supply from the internal thoracic artery, the superior intercostal artery, descending thoracic aorta, superior thoracic and the subcostal arteries. The pattern of vascular distribution is similar to the structure of the thoracic cage and runs along the intercostal spaces.

Internal Thoracic Artery and Anterior Intercostal Arteries

The internal thoracic artery is also called as the internal mammary artery. It arises from the first part of the subclavian artery in the lower part of the neck. It descends behind the clavicle and the first to sixth costal cartilages lying about 1 cm lateral to the sternal margin. It terminates in the sixth intercostal space by dividing into the ***musculophrenic*** and ***superior epigastric*** arteries. Below the level of the second costal cartilage, the artery lies anterior to the transversus thoracis muscular slips. It also gives out various other branches (Fig. 5.11).

- Along its course, the internal thoracic artery gives off a series of ***anterior intercostal arteries*** to the upper 6 intercostal spaces. There are two arteries (a pair) to each intercostal space. They pass laterally, one along the inferior border of the superior rib and the other along the superior border of the inferior rib. In the space, the upper of the two anastomoses with the main stem of the posterior intercostal artery and the lower with the collateral branch of the latter. The anterior intercostal arteries of a particular intercostal space usually arise as two separate branches from the internal thoracic artery; rarely, a single branch is given out which then divides into two. These arteries supply the intercostal muscles

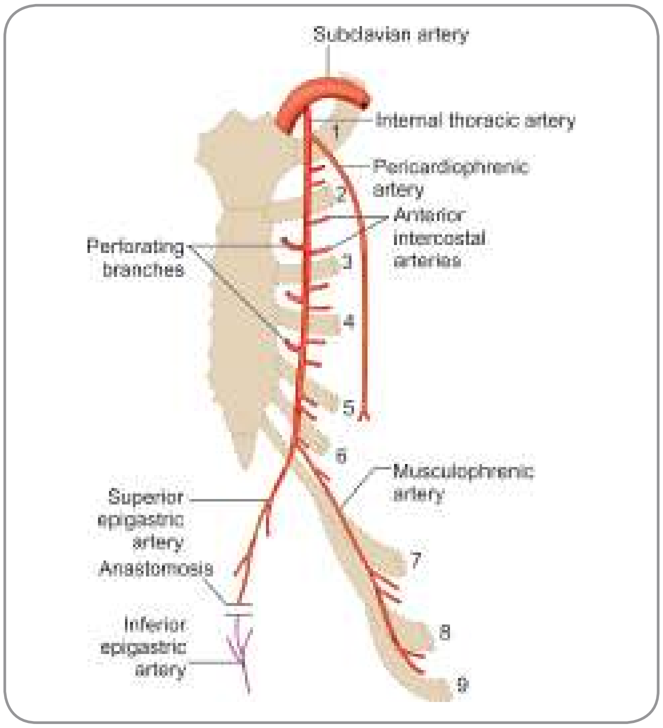


Fig. 5.11: Internal thoracic artery and its branches. The skeletal elements are drawn as if transparent

and then send branches which pierce through to reach the pectoral muscles, breast and skin.

- The ***pericardiophrenic branch*** (pericardiacophrenic artery) is given off near the upper end of the internal thoracic artery. It runs downwards along the phrenic nerve to reach the diaphragm and gives branches to pleura and pericardium.
- ***Perforating branches*** pass forwards through the thickness of the upper five or six intercostal spaces to supply the pectoralis major muscle and the breast (especially in the 2nd to 4th spaces). These arteries are larger in females.
- The ***musculophrenic artery*** is the lateral terminal branch of the internal thoracic artery. It passes downwards and laterally deep to the costal margin and enters the abdominal wall by passing through an aperture in the diaphragm. The anterior intercostal arteries to the 7th to 9th intercostal spaces (which follow the same course as that of the higher intercostal arteries) are given out by the musculophrenic artery as it runs towards the diaphragm. The lower part of pericardium and the abdominal muscles are also supplied by it.
- The ***superior epigastric artery*** is the medial terminal branch of the internal thoracic artery. Soon after its origin, it passes from the thorax into the abdomen through the interval between the costal and xiphoid origins of the diaphragm. It gives off some branches to the anterior mediastinum (to thymus and lymph nodes), to pericardium and to the diaphragm.

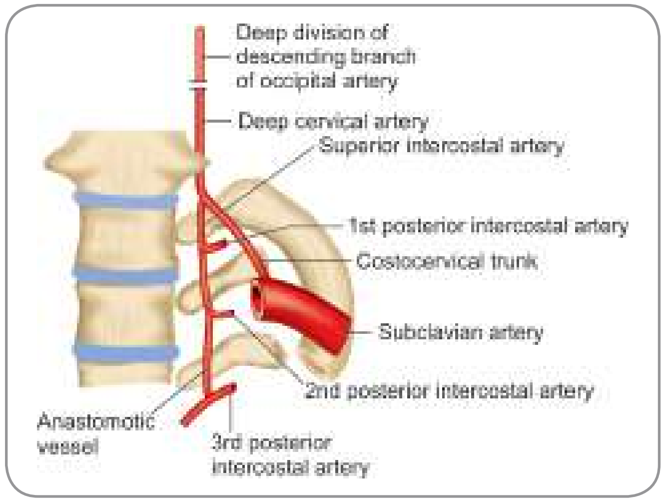


Fig. 5.12: Scheme to show the origin of superior intercostal artery

Superior Intercostal Artery

The superior intercostal artery (or the supreme intercostal artery) arises from the costo cervical trunk which is a branch of the subclavian artery. It runs downwards behind the cervical pleura and descends across the neck of the first rib to reach the first intercostal space where it gives off the first posterior intercostal artery. The artery then descends across the second rib and becomes the second posterior intercostal artery and anastomoses with a branch of the third posterior intercostal artery (Fig. 5.12).

Posterior Intercostal Arteries (Fig. 5.13)

There are usually nine pairs of posterior intercostal arteries. They arise from the posterior aspect of the

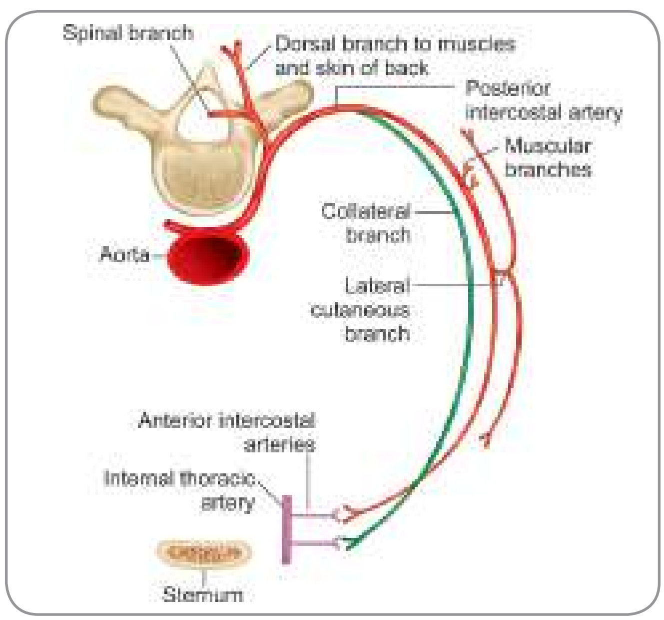


Fig. 5.13: Scheme to show course and branches of a typical posterior intercostal artery

descending thoracic aorta and are distributed to the lower nine intercostal spaces as the arteries for the first and second spaces arise from the superior intercostal artery. Each posterior intercostal artery runs backwards on the side of the body of the numerically corresponding vertebra to reach the corresponding intercostal space where it lies in the costal groove of the rib forming the upper boundary of the space. Within the space, the artery lies between the internal intercostal muscle (second layer) and the innermost intercostal muscle (third layer). It is accompanied by the corresponding vein above and the intercostal nerve below except in the first intercostal space, where the nerve lies above the artery. The artery ends by anastomosing with the corresponding anterior intercostal artery at the anterior end. At places where the artery is not covered by the intercostalis intimi, it is directly in contact with the parietal pleura which separates it from the visceral pleura and lung. As the descending aorta lies somewhat to the left of the median plane, the right posterior intercostal arteries (arising from it) are longer than arteries of the left side. On either side, the posterior intercostal arteries pass deep to the sympathetic trunk. On the right side, they also pass deep to the azygos vein and the thoracic duct. Each posterior intercostal artery gives off a number of branches.

- Before entering the intercostal space the artery gives off a ***dorsal branch*** that supplies muscles and skin of the back. The dorsal branch gives off a spinal branch that supplies the spinal cord and vertebrae.
- The ***collateral branch*** arises near the angles of the corresponding ribs. It then runs parallel to the main artery, but along the upper border of the rib below the intercostal space and anastomoses with the lower of the two anterior intercostal arteries in the same space.
- A number of ***muscular branches*** supply intercostal muscles and other muscles lying over the thoracic wall. The lower two posterior intercostal arteries continue into the abdominal wall and help to supply it.
- A ***lateral cutaneous branch*** arises about midway between the anterior and posterior ends of the intercostal space. It divides into anterior and posterior branches that supply the skin over the thorax and part of abdomen.
- The 2nd, 3rd, 4th posterior intercostal arteries give branches to the mammary gland. These are larger in the females.
- The right bronchial artery arises from the right third posterior intercostal artery.

Subcostal Arteries

The subcostal arteries are the last paired branches of the thoracic aorta in series with the posterior intercostal arteries but lie below the twelfth rib. On each side, the artery runs across the lateral side of the twelfth thoracic vertebra. After a short course in the thorax, the artery enters the abdomen by passing under cover of the lateral arcuate ligament. The subcostal artery supplies some muscles in the walls of the thorax and abdomen and gives off a ***dorsal branch***, the distribution of which is similar to that of the corresponding branches of the posterior intercostal arteries.

Added Information

The anterior intercostal arteries to the inferior two intercostal spaces are usually absent. These spaces are supplied by the posterior intercostal arteries and their collaterals.

VEINS OF THORACIC WALL

The thoracic wall is drained anteriorly by the internal thoracic veins and posteriorly by the azygos system of veins. However, the drainage starts from the intercostal veins.

Posterior Intercostal Veins

Each intercostal space is drained by a ***posterior intercostal vein*** that corresponds to the posterior intercostal artery. There are eleven intercostal veins and one subcostal vein on each side. These veins start from multiple small venules in each space and run in a posterior direction. As it approaches the vertebral column, it receives a posterior tributary which drains the region of the spinal nerve of that level and an intervertebral vein that drains the vertebral venous plexus.

The termination of the posterior intercostal veins is as follows (Fig. 5.14):

- On either side (right or left), the vein of the first space (called the ***highest intercostal vein***) ascends in front of the neck of the first rib and arches over the cervical pleura to end in the corresponding brachiocephalic vein.
- The veins of the 2nd and 3rd spaces (and sometimes those of the 4th) join to form the superior intercostal veins. The ***left superior intercostal vein*** runs upwards and forwards on the left side of the arch of the aorta and ends in the left brachiocephalic vein. The ***right superior intercostal vein*** joins the terminal part of the azygos vein.
- On the right side, the remaining posterior intercostal veins (4 to 11) end directly in the azygos vein.
- On the left side, the veins from the 4th to 8th spaces end in the ***accessory hemiazygos vein.***
- The veins of the 9th, 10th and 11th spaces (on the left side) end in the ***hemiazygos vein.***

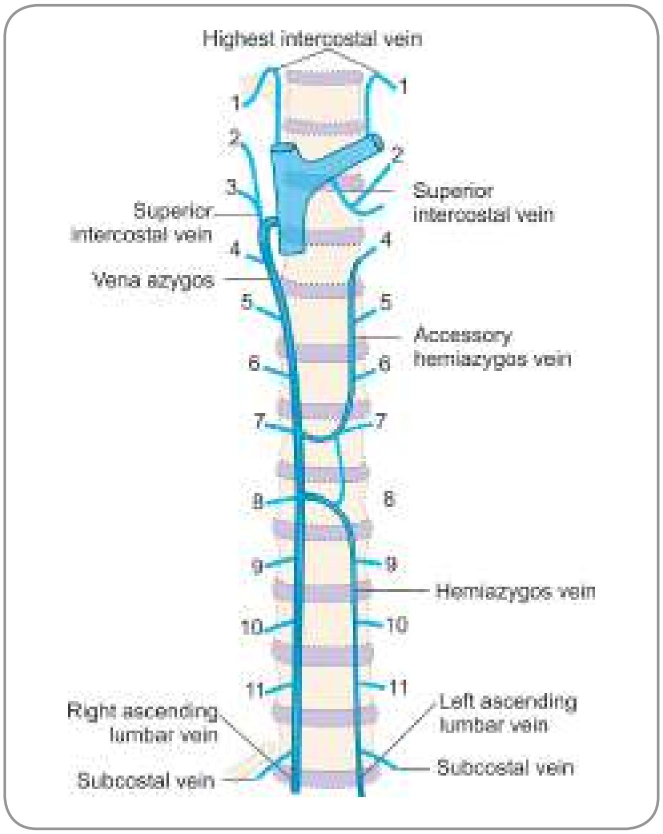


Fig. 5.14: Scheme to show formation of azygos vein
1 to 11—intercostal veins

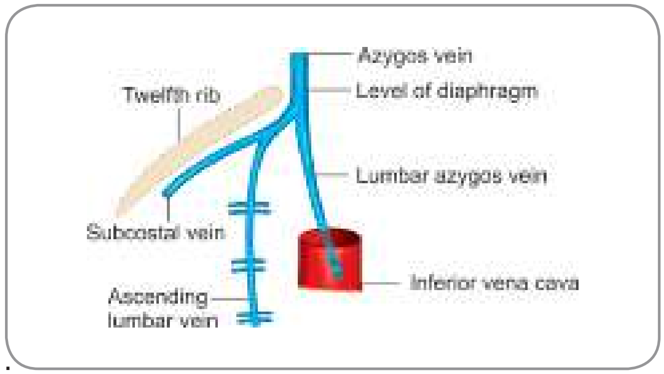


Fig. 5.15: Azygos veins

Internal Thoracic Vein

The ***internal thoracic vein*** accompanies the corresponding artery and has tributaries corresponding to the branches of the artery. The anterior intercostal veins drain into the internal thoracic veins.

Azygos System of Veins

Azygos Vein

Azygos means "unpaired". It is called so since the ***azygos vein*** is present only on the right side. It begins in the abdomen by the union of the lumbar azygos, the right subcostal and the right ascending lumbar veins. The internal thoracic veins drain into the corresponding brachiocephalic veins.

The ***lumbar azygos vein,*** when present, typically starts from the posterior aspect of inferior vena cava and ascends anterior to the upper lumbar vertebrae.It may either enter the thoracic cavity through the aortic opening or may pierce the right crus of the diaphragm. Anterior to the twelfth thoracic vertebral body,the azygos is joined by a large vessel formed by the union of right ascending lumbar vein and right subcostal vein. The ***right subcostal vein*** accompanies the corresponding artery.The ***ascending lumbar vein*** is a vertical channel connecting the lumbar veins to one another.

The lumbar azygos vein is sometimes absent and in that case the azygos vein is formed only by the right subcostal and right ascending lumbar veins.It then ascends vertically along the right side of the vertebral column up to the level of the fourth thoracic vertebra (Fig. 5.15). Here, it arches forwards above the root of the right lung and ends in the superior vena cava. The azygos vein is related, on its right side, to the right pleura and lung. On its left side, it is related to the aorta and to the thoracic duct. Its terminal part crosses the trachea, the oesophagus and the right vagus nerve.

Hemiazygos Vein

The ***hemiazygos vein*** is present only on the left side. It is formed by the union of the left ascending lumbar and left subcostal veins. Its tributaries are the lower three posterior intercostal veins and some oesophageal and mediastinal veins. It ascends on the left side of the bodies of the lower thoracic vertebrae and at the eighth thoracic level crosses the vertebral column posterior to the aorta, oesophagus and thoracic duct to end in the azygos vein.

Accessory Hemiazygos Vein

The ***accessory hemiazygos vein*** descends vertically on the left side of the bodies of upper thoracic vertebrae and receives fourth to eighth posterior intercostal veins. The lower end of the vein turns to the right across the front of the 7th thoracic vertebra and ends by joining the azygos vein.

The terminal parts of the hemiazygos and accessory hemiazygos veins lie behind the descending thoracic aorta. They may unite to form a common channel, or may communicate with each other.

NERVES OF THORACIC WALL

The thoracic wall is supplied by the thoracic spinal nerves. There are twelve pairs of thoracic spinal nerves, each pair emerging from the vertebral canal below the corresponding vertebra. Each nerve divides into a dorsal ramus and a ventral ramus. The dorsal rami are smaller than the ventral rami. They pass backwards and divide into medial and lateral branches which supply the muscles and the skin of the back.

The ventral rami of the T1 to T11 form the intercostal nerves and the ventral ramus of T12 is the subcostal nerve.

Intercostal Nerves

The ventral rami of the thoracic nerves run into the thoracic wall as the intercostal and subcostal nerves. There are twelve ribs on either side, eleven intercostal spaces, with each space having one intercostal nerve. The intercostal nerves are numbered from above downwards. The twelfth pair of nerves lie below the twelfth ribs and are called the ***subcostal nerves.*** The first two intercostal nerves supply fibres to upper limb in addition to their thoracic branches, the next four supply the thoracic wall only while the lower five supply both the thoracic and abdominal walls. Hence the 3rd, 4th, 5th and 6th intercostal nerves are considered typical intercostal nerves.

Typical Intercostal Nerves

Each intercostal nerve runs forwards in the concerned intercostal space lying between the second and third layers of muscles (Fig. 5.16). Posteriorly, each nerve lies between the pleura and the posterior intercostal membrane; and then between the internal intercostal muscle on the outside and the subcostalis and the innermost intercostal muscle on the inside. Near the anterior end of the space, the nerve crosses anterior to transversus thoracis muscle and internal thoracic vessels. Finally, the nerve becomes superficial by piercing the internal intercostal muscle, the anterior intercostal membrane and the pectoralis major to become the ***anterior cutaneous nerve of the thorax*** (Fig. 5.16).

Near the angle of the rib, the nerve passes to the costal groove and continues in it. In the costal groove, the nerve lies immediately below the intercostal artery, which in turn lies below the intercostal vein (Fig. 5.17). The neurovascular bundle is thus overlapped and sheltered by the inferior border of the rib.

The intercostal nerves are distributed to both muscles and skin through a number of branches. The main branches are the ***collateral branch*** and the ***lateral cutaneous branch***.

- The collateral branch that is given out near the angle of the rib, runs forwards in the lower part of the intercostal space and along the superior border of the rib below. Its relationships are similar to those of the main nerve. It supplies the parietal pleura and the intercostal muscles.
- The lateral cutaneous branch that is given out at the midaxillary line, runs along the parent nerve for some distance. It then turns laterally to pierce through the internal and external intercostal muscles (and other muscles which overlie them) and becoming subcutaneous, divides into anterior and posterior branches which supply the skin over the thoracic wall. The lateral cutaneous branch of the second intercostal nerve does not divide, and joins the medial cutaneous nerve of arm as the intercosto-brachial nerve.
- In addition to these large branches, each intercostal nerve gives several branches that supply the intercostal muscles. They also supply other muscles like the transversus thoracis, levatores costarum, subcostal and serratus posterior muscles.

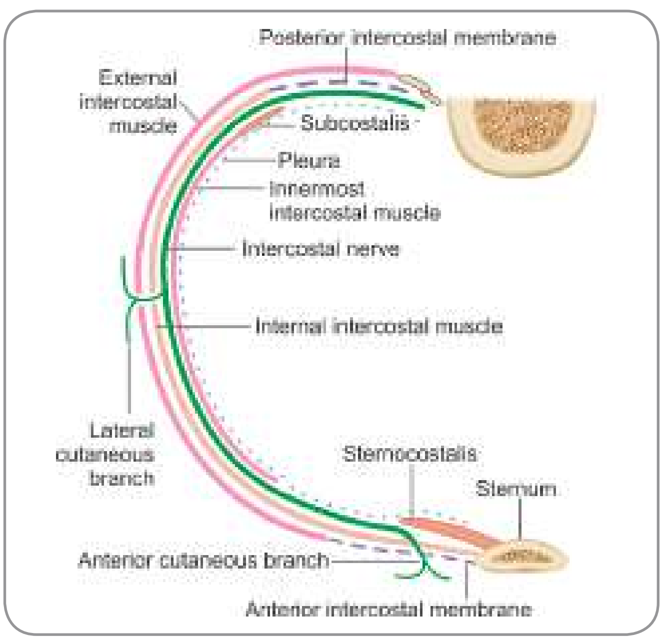


Fig. 5.16: Course and relations of a typical intercostal nerve

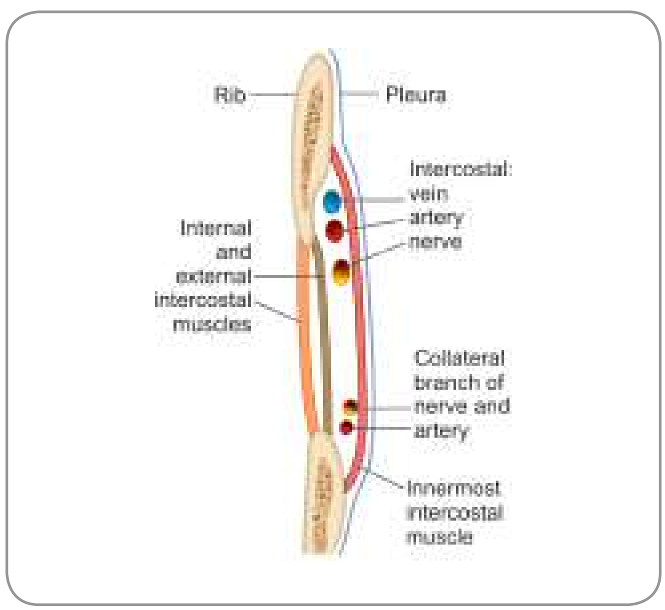


Fig. 5.17: Vertical section through an intercostal space showing the position of nerves and vessels

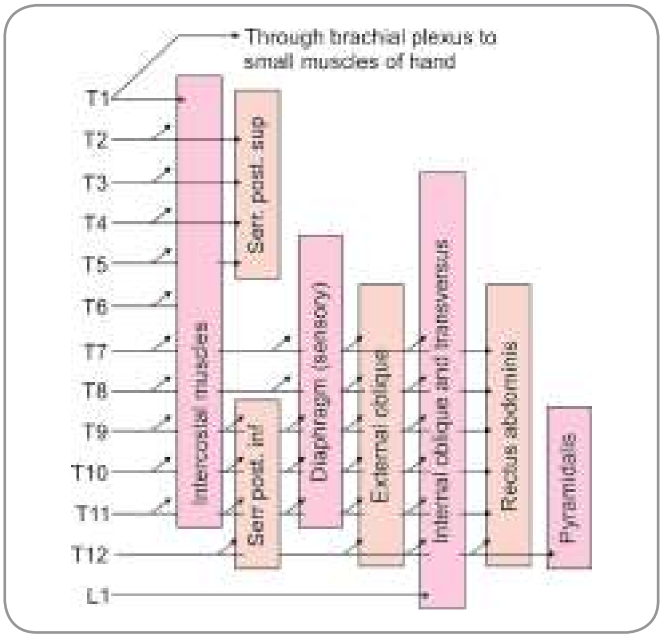


Fig. 5.18: Scheme to show muscles supplied by ventral rami of thoracic nerves (Serr. post. inf.—serratus posterior inferior; Serr. post. sup.—serratus posterior superior)

- The anterior cutaneous branch pierces the muscles and membranes of the intercostal space in the parasternal line; it then divides into medial and lateral branches which supply the skin of the anterior aspect of the thoracic wall (Fig. 5.16).
- Rami communicantes are branches which connect each intercostal nerve to the ipsilateral sympathetic trunk. Preganglionic fibres leave the intercostal nerve and reach the sympathetic trunk through the white rami; postganglionic fibres arising from the sympathetic trunk pass through the grey rami to the intercostal nerve and get distributed through the various branches to blood vessels, sweat glands and smooth muscles of thoracic wall.

Atypical Intercostal Nerves

The ventral rami of the 3rd to 6th thoracic spinal nerves behave as typical intercostal nerves. The rest of them have some modifications warranting their classification as atypical intercostal nerves.

- The ventral ramus of the first thoracic spinal nerve divides into a larger superior and a smaller inferior branch. The superior branch joins the brachial plexus. The inferior branch becomes the first intercostal nerve. It has no collateral branch and does not usually give out a lateral cutaneous branch. If a lateral cutaneous branch is given out in rare cases, it supplies the skin of axilla (Fig. 5.19).
- The first and second intercostal nerves run along the internal surfaces of the first and second ribs.

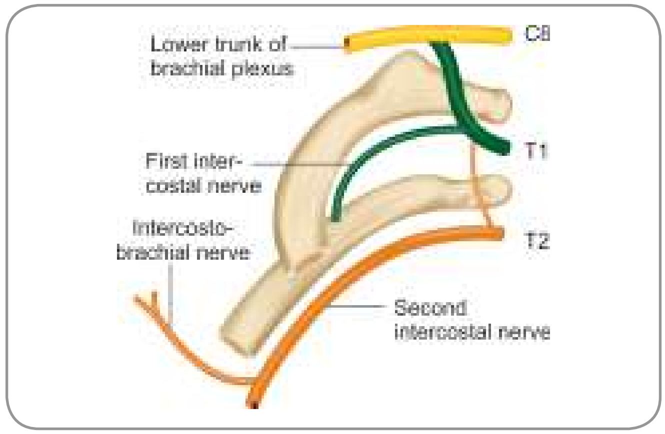


Fig. 5.19: Fate of ventral rami of the first and second thoracic nerves

- The second intercostal nerve gives out a lateral cutaneous branch called the intercostobrachial nerve (Fig. 5.19). Emerging at the midaxillary line of the second intercostal space, it pierces the serratus anterior and reaches the axilla. After supplying the skin and fasciae of axilla, it joins with the medial cutaneous nerve of arm.
- The third intercostal nerve frequently gives out a lateral cutaneous branch, which becomes the second intercostobrachial nerve.

Lower Intercostal Nerves

The initial parts of the seventh, eighth, ninth, tenth and eleventh intercostal nerves resemble those of typical intercostal nerves described above. However, on reaching the anterior end of the intercostal space concerned, each nerve passes deep to the costal margin to enter the abdominal wall. They are no longer intercostals, but become thoracoabdominal nerves.

The intercostal nerves run forward in the abdominal wall lying between the second and third layers (just as in the intercostal spaces). Reaching the rectus abdominis, they pierce the posterior layer of its sheath to enter the muscle. The nerves then pass forwards through the rectus abdominis to reach the skin and supply it (Fig. 5.20). The course of the seventh and eighth intercostal nerves is slightly different from that described above because the anterior ends of the corresponding spaces lie behind the rectus abdominis. These nerves, therefore, do not travel any part of their course between the internal oblique and transversus muscles, but enter the rectus sheath directly.

The seventh to eleventh intercostal nerves give off:

- ***Collateral branches*** that run parallel to the main trunks. Like the parent trunks, they enter the abdominal wall, and pierce the rectus abdominis to reach the skin over it.
- ***Lateral cutaneous branches*** which become superficial by piercing the internal and external intercostal

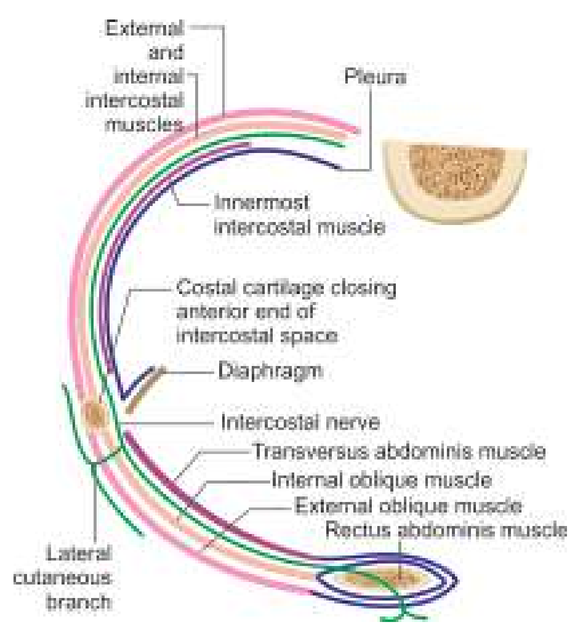


Fig. 5.20: Scheme to show the course of one of the lower intercostal nerve. The intercostal space and the abdominal wall are cut along the course of the nerve

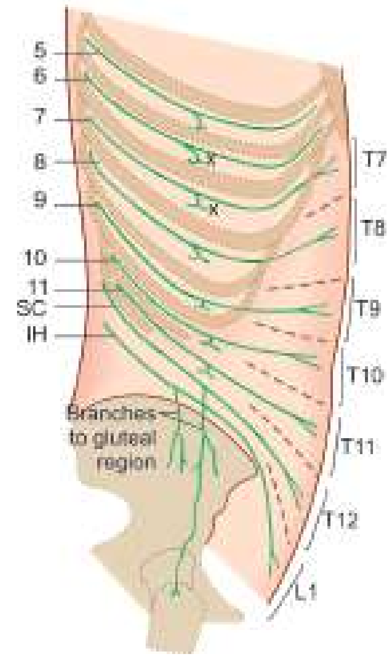


Fig. 5.21: Course of intercostal nerves as seen from the lateral side. **Key: SC.** Subcostal nerve **IH.** Iliohypogastric nerve

muscles, or the internal and external oblique muscles of the abdomen, divide into anterior and posterior branches that supply the skin of the trunk ('x' in Fig. 5.21).

It will be seen that the lower intercostal spaces turn upwards near the anterior ends. The seventh and eighth intercostal nerves follow this curve even after they enter the abdomen, so that they run upwards and medially in the abdominal wall. The course of the ninth nerve within the abdominal wall is horizontal. The tenth and eleventh nerves run downwards and medially.

Clinical Correlation

- ***Supernumerary ribs:*** There are twelve pairs of ribs normally. However, the number is increased in case of cervical or lumbar ribs.
- ***Rib fractures:*** Injuries to the chest, especially blows, can cause rib fractures. Since the first rib lies in a protected position, it is rarely fractured. The middle level ribs are fractured commonly. The part of a rib immediately anterior to its angle is the weakest. Fractures of lower ribs may cause diaphragmatic tears in turn leading to diaphragmatic hernia. Fracture of rib causes intense pain.
- ***Flail chest:*** The thoracic cage may be fractured in multiple places. This causes a portion of the thoracic wall to move freely. This loose and free segment moves paradoxically—inward during inspiration and outward during expiration. Respiration is affected.
- When there is a necessity to enter the thoracic cavity, an opening is created. This is called thoracotomy. An anterior thoracotomy cuts through the perichondrium of costal cartilages and shells out the cartilages to enter the cavity. Posterior thoracotomy is usually attempted through the posterolateral aspects of the 5th, 6th and 7th intercostal spaces. Lateral thoracotomy is the most preferred.
- The costal cartilages undergo age changes. As age advances, they lose their elasticity. They also become brittle. Due to their losing resilience, they also become radiopaque and appear whitish in radiographs.
- ***Medial sternotomy:*** Colloquially known as 'sternal splitting', this procedure is adopted during certain thoracic surgeries. The sternum is split in the midline. After the surgery, the two halves are sutured or wired.
- ***Rib dislocation and separation:*** When a costal cartilage slips out from its sternal attachment, it is called rib dislocation or slipping rib. It is actually a dislocation of the sternocostal joint or displacement of an interchondral joint. Dislocation at a costochondral joint causes rib separation. Both these are extremely painful and can produce damage to any of the underlying structures.
- ***Intercostal nerve block:*** This is a procedure adopted for anaesthetizing the intercostal space. The anaesthetic agent is infiltrated around the intercostal nerve and its collateral branch.
- ***Substernal pain:*** 'Chest pain' is a common occurence and very many causes contribute to it. Though chest pain can occur in lung diseases, intestinal and gall bladder diseases and in musculoskeletal problems of the thoracic wall, it is also the most important symptom of cardiac disease. Chest pain originating from cardiac causes (especially from 'heart attacks') is usually described as a 'crushing' (something heavy sitting up and compressing) pain in the sub-sternal area by the people who suffer it; this pain does not disappear with rest.

Multiple Choice Questions

1. The internal intercostal muscles are replaced posterior to the angles of ribs by:
   a. Innermost intercostal muscles
   b. Subcostal muscles
   c. Transversus thoracis muscles
   d. Internal intercostal membranes
2. The central part of the dome of diaphragm is at the level of:
   a. Xiphisternal joint
   b. Lower end of xiphoid
   c. T7 vertebra
   d. T 10 vertebra
3. What is false about the opening for inferior vena cava?
   a. It lies at the level of T8 vertebra
   b. It is highest of the three major openings of the diaphragm
   c. It is almost always closed by the collapse of the walls of the vena cava
   d. It transmits the right phrenic nerve
4. The anterior intercostal arteries to the 7th to 9th intercostal spaces arise from the:
   a. Internal thoracic artery
   b. Pericardiacophrenic artery
   c. Musculophrenic artery
   d. Superior epigastric artery
5. To form the intercostobrachial nerve, the lateral cutaneous branch of the second intercostal nerve joins with the:
   a. Medial cutaneous nerve of arm
   b. First intercostal nerve
   c. Lateral cutaneous branch of the third intercostal nerve
   d. Collateral branch

ANSWERS

1. d **2.** a **3.** c **4.** c **5.** a

Clinical Problem-solving

Case Study 1: A 57-year-old man has pleural effusion. Paracentesis is being planned for him. You are being consulted for the decision on the exact location of the procedure.

- What is the choice of location in this case?
- On choosing a particular intercostal space, what further precaution would you exercise?
- Enumerate the structures through which the aspiration needle passes.

Case Study 2: A 68-year-old woman has a rolling hiatus hernia.

- Explain a rolling hiatus hernia in anatomical terms.
- Which anatomic structure is at fault?
- Why will there not be any gastro-oesophageal reflux in this case?

(For solutions see Appendix).

Chapter **6**

Thoracic Cavity, Mediastinum and Pleural Cavities

Frequently Asked Questions

- Discuss the mediastinal surfaces of the right and left lungs.
- Write notes on: (a) Superior mediastinum, (b) Thymus, (c) Parietal pleura, (d) Pleural recesses.
- Discuss the bronchopulmonary segments in detail.
- Write briefly on: (a) Trachea, (b) Hilum of right lung, (c) Pleura

INTRODUCTION TO THE RESPIRATORY SYSTEM

The respiratory system is meant, primarily, for the oxygenation of blood. The chief organs of the system are the ***right*** and ***left lungs***. Oxygen contained in air reaches the lungs by passing through a series of respiratory passages which also serve for removal of carbon dioxide released from the blood. Air from outside enters the body through the ***right*** and ***left anterior nares*** (or ***external nares***) which open into the right and left ***nasal cavities*** (Fig. 6.1). At the posterior ends of these cavities, air passes through openings called the ***posterior nares*** (or ***internal nares***) which open into the ***pharynx***. The pharynx is divisible, from above downwards, into: (a) an upper part—the ***nasopharynx*** (into which the nasal cavities open); (b) a middle part—the ***oropharynx*** (that is continuous with the posterior end of the oral cavity); (c) and a lower part—the ***laryngopharynx***.

Air from the nose enters the nasopharynx and passes down through the oropharynx and laryngopharynx. Air can also pass through the mouth directly into the oropharynx and from there to the laryngopharynx. Air from the laryngopharynx enters the ***larynx*** (Fig. 6.1). Apart from being a respiratory passage it is the organ where voice is produced.

Inferiorly, the larynx is continuous with ***trachea*** (Fig. 6.2) that passes through the lower part of the neck into the upper part of the thorax. At the level of the lower border of the manubrium sterni, the trachea bifurcates into right and left ***principal bronchi*** which carry air to the right and left lungs (Fig. 6.2).

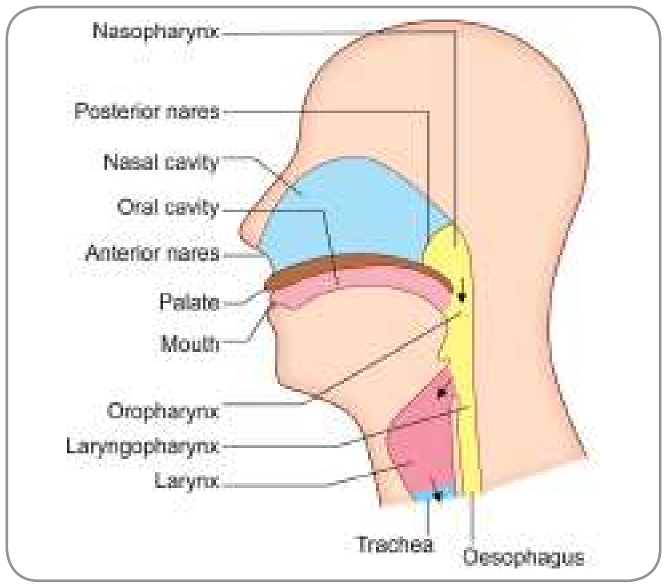


Fig. 6.1: Simplified diagram showing intercommunications between the nasal cavities, the mouth, the pharynx, the larynx and the oesophagus

Within the lung, each principal bronchus divides, like the branches of a tree, into smaller and smaller ***bronchi*** that ultimately end in microscopic tubes called ***bronchioles*** which, in turn, open into microscopic sac-like structures called ***alveoli*** (Fig. 6.2). The walls of the alveoli contain a rich network of blood capillaries. Blood in these capillaries is separated from the air in the alveoli by a very thin membrane through which gaseous exchange occurs.

Deoxygenated blood enters the lungs through pulmonary arteries, and passes into numerous pulmonary capillaries which surround the alveoli where gaseous exchanges take place. The substance of the lung contains

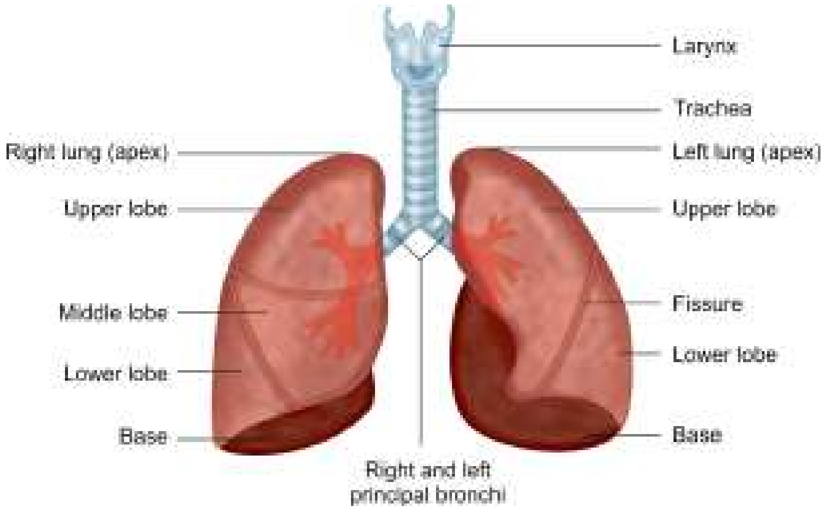


Fig. 6.2: Larynx, trachea and lungs as seen from the front

abundant elastic tissue that plays an important role in respiration.

RESPIRATION

Breathing is a highly coordinated process involving both abdomen and thoracic regions. The diaphragm is the main muscle of inspiration responsible for two-thirds of quiet breathing in humans. The external intercostal muscles are most active in inspiration and the internal intercostal muscles in expiration. The contraction of the inspiratory muscles increases the vertical, transverse and anteroposterior dimensions of the chest which in turn increase the volume of the pleural space. There is a resultant decrease in the intrapleural pressure; this results in drawing of air into the lungs by exerting pull on elastic tissue within the lungs causing them to expand.

The reverse happens during expiration. Muscles which are responsible for the expansion of thorax are now relaxed and the cavity becomes smaller, expelling air to the outside. Expiration is also aided by the recoil of elastic tissue within the lung.

The main force for inspiration is provided by the diaphragm. During inspiration, the lower ribs are fixed and contraction of the diaphragm draws the central tendon downwards (called the ***descent of diaphragm***) increasing the vertical diameter of the thorax. The movement of the central tendon downwards causes the abdominal viscera to move downwards which is made possible by the extensibility of the anterior abdominal wall. However, the movement of the central tendon is limited by the resistance offered by the abdominal muscles and viscera. Once the movement of the central tendon is fixed by the abdominal viscera, it acts as a fixed point. With the continuing contraction of the diaphragm, the second to tenth ribs are elevated and the inferior portions of the ribs are turned outwards. This results in the elevation of the medial aspects of the ribs thereby increasing the transverse dimension of the chest. This movement is called the ***'bucket handle movement'*** (due to the similarity to the handle of a bucket being lifted) and is most evident in the lower ribs. Simultaneously, movements at the costovertebral joints cause elevation of the anterior ends of the ribs that push the body of sternum and the upper ribs forwards, thereby increasing the antero-posterior dimension of the chest. This is called the ***'pump handle movement'*** and is most evident in the upper ribs and increases the antero-posterior dimension of the thorax. The right cupola of the diaphragm which lies over the liver needs to overcome a higher resistance than that of the left side which is over the fundus of the stomach; hence the fibres of the right crus have a greater attachment to the lumbar vertebrae.

The balance between the descent of diaphragm, protrusion of abdominal wall (abdominal breathing) and elevation of ribs (thoracic breathing) differs among individuals and even in the same individual, with the depth of ventilation. Abdominal breathing is more marked in infants and young children as the thoracic cavity is almost circular in cross section and scope for anteroposterior or side- to-side expansion is limited, while thoracic breathing is more commonly seen in females.

Acting along with the muscles of the anterior abdominal wall, the diaphragm also helps to increase the intra-abdominal pressure during acts like micturition, defaecation or vomiting. The acts requiring forcible expulsion of air from the lungs like sneezing or laughing are preceded by a deep inspiration (diaphragm), followed by contraction of the expiratory muscles.

The primary role of the intercostal muscles is to stiffen the chest wall preventing paradoxical motion during descent of the diaphragm in inspiration.

Other Effects of Respiration

The fibrous pericardium is adherent to the central tendon of the diaphragm. Hence when the diaphragm descends, the heart is also pulled downwards. As a result, the mediastinum becomes longer, but narrower. The reverse happens in expiration. Similarly, increase in anteroposterior diameter of the thorax also stretches the mediastinum anteroposteriorly.

> **Clinical Correlation**
>
> - ***Effects of Injury to Thoracic Wall on Respiratory Movements:*** Fracture of ribs at two or more sites will affect the integrity of the thoracic wall. The loose (or flail) segment moves inwards with inspiration and outwards during expiration. This condition is called ***flail chest***. When the ribs are fractured on either side of the sternum, the sternum can also become flail.
> - ***Paradoxical Respiration:*** In normal respiration, pressure within the pleural cavity falls during inspiration which is responsible for the filling up of the lungs. When there is an open pneumothorax, the pressure in the pleural cavity ***increases*** during inspiration (because of entry of air from outside) leading to partial collapse of the lung. This condition is called ***paradoxical respiration*** because the lung expands during expiration and becomes smaller during inspiration.
> - ***Empyema Necessitans:*** It is an abscess formed over the thoracic wall caused secondary to the collection of pus in the pleural cavity (***empyema***). The pus usually traverses to the chest wall along the track of a needle used for aspiration and present as an abscess.
> - ***Thoracotomy:*** An opening made in the thoracic wall to access the thoracic cavity surgically is called ***thoracotomy***. Depending upon the region to be approached, thoracotomy can be anterior, posterior or lateral.

THORACIC CAVITY

The thoracic cavity is more or less oval with the transverse diameter being greater than the anteroposterior diameter. Posteriorly, the vertebral column projects forward into the cavity and on each side of it, the thoracic cavity extends backwards to the level of the transverse processes of vertebrae. The backward extensions of the thoracic cavity, on either side of the vertebral column, are called the ***paravertebral grooves*** or paravertebral gutters. The lateral walls of the cavity are formed by ribs and intercostal muscles and the dome-shaped diaphragm closes the cavity inferiorly.

The inlet of the thorax slopes downwards and forwards. The level of the upper border of the manubrium sterni corresponds to the level of the intervertebral disc between T2 and T3. The diaphragm is attached anteriorly to the xiphoid process, and passes backwards to reach the vertebral column at level T12.

SUPERIOR THORACIC APERTURE

At its upper end, the thoracic cage has an opening called the ***superior thoracic aperture***. This aperture is bounded posteriorly by the upper end of the body of the first thoracic vertebra, laterally, by the inner border of the first rib, and in front by the upper border of the manubrium sterni. As the upper border of the manubrium sterni lies at the level of the lower border of vertebra T2, the superior aperture is not placed horizontally, but has a slope that runs downwards and forwards. The superior aperture gives passage to several structures which pass from the neck into the thorax, or ***vice versa***. These include the trachea, the oesophagus, several large blood vessels and nerves.

INFERIOR THORACIC APERTURE

At its lower end, the thoracic cage has an inferior aperture that is much larger than the superior aperture (the size of the superior aperture corresponds to the diameter of the neck; and that of the lower aperture to the diameter of the upper part of the abdomen). ***Anteriorly***, the boundary of the inferior aperture is V-shaped and is formed (in each half) by the 7th, 8th, 9th and 10th costal cartilages. This boundary, that passes downwards and laterally from the xiphoid process, is called the ***costal margin***. It can be easily palpated in a living person and is an important landmark. ***Posteriorly***, the inferior aperture of the thorax is bounded, in the median plane, by the lower border of the 12th thoracic vertebra, and more laterally by the 12th pair of ribs. ***Below***, the inferior aperture is closed by the ***diaphragm***. The diaphragm is not flat, but has a marked upward convexity. The uppermost part of the abdominal cavity, therefore, lies under cover of the lower part of the thoracic cage. Structures passing from the thorax to the abdomen have to pass through apertures in the diaphragm.

MEDIASTINUM

Within the thoracic cavity, are present the major organs, namely the heart and a pair of lungs. The right and left sides of the thoracic cavity are almost completely filled by the corresponding lungs. Between the lungs and the pleural cavities is the mediastinum in the middle. It is defined as a region between the two pleural sacs bounded anteriorly by the sternum, posteriorly by the thoracic vertebral column and extending vertically between the thoracic inlet and the diaphragm. The heart, trachea, oesophagus, and several large vessels lie within the mediastinum (Fig. 6.3).

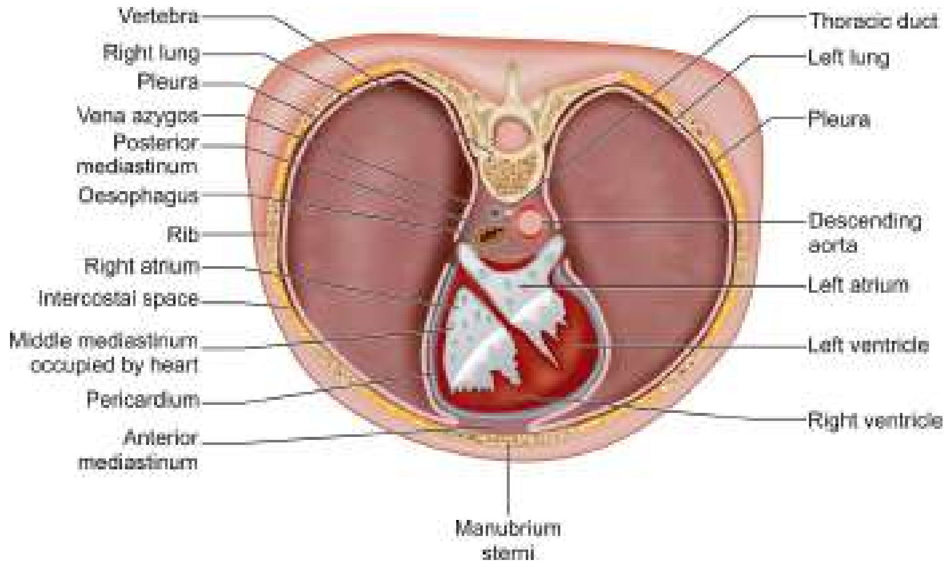


Fig. 6.3: Transverse section through thorax showing important contents

The mediastinal space is further broadly divided into ***superior mediastinum*** and ***inferior mediastinum*** by an imaginary plane passing through the manubriosternal joint (at the level of the lower border of manubrium sterni/sternal angle/angle of Louis) and the lower part of 4th thoracic vertebra (Fig. 6.4). The ***inferior mediastinum*** is further subdivided into ***anterior***, ***middle*** and ***posterior mediastina***. Within the inferior mediastinum, the greater part of the area occupied by the heart with its great vessels is called the ***middle mediastinum***. The part of the inferior mediastinum in front of the heart is the ***anterior mediastinum*** and the part behind is the ***posterior mediastinum*** (Fig. 6.4).

SUPERIOR MEDIASTINUM

The superior mediastinum lies between the manubrium sterni and the upper four thoracic vertebrae. It is bounded

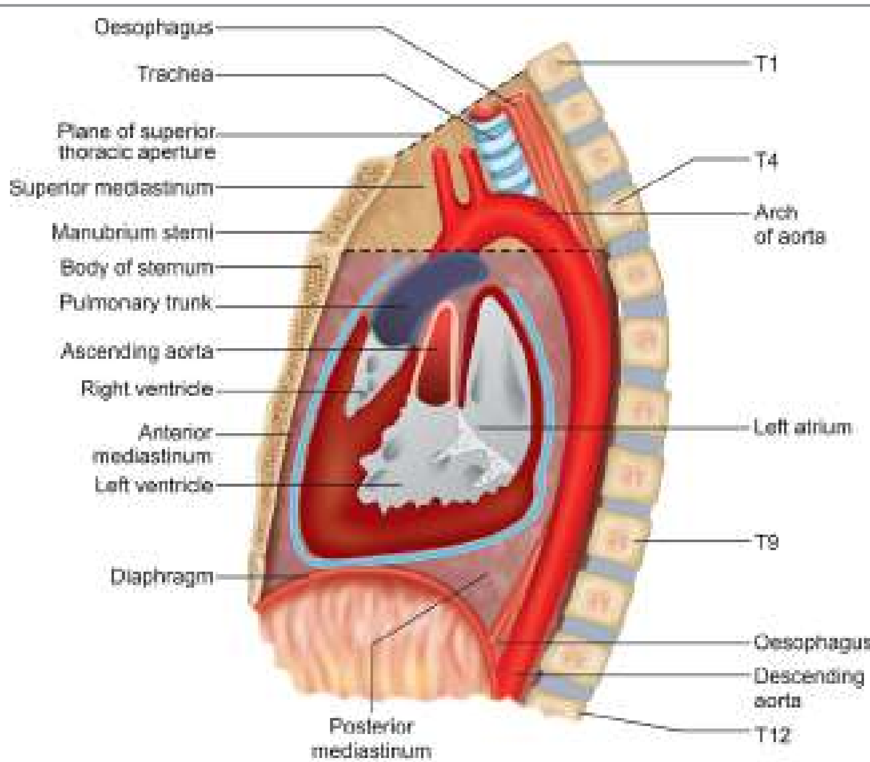


Fig. 6.4: Schematic sagittal section through the thorax to show the subdivisions of the mediastinum

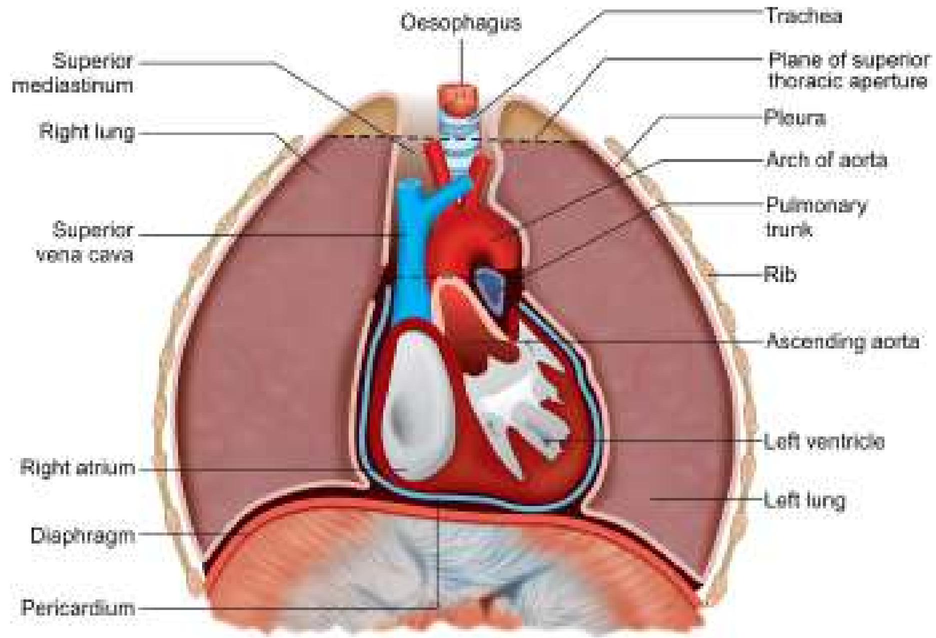


Fig. 6.5: Schematic coronal section through thorax to show its main contents

below by the imaginary plane passing through the sternal angle and T4 vertebra, above by the superior thoracic aperture and laterally by the mediastinal pleurae (Fig. 6.5).

Contents (From Before Backwards)

- ***Retrosternal structures***
  - Lower ends of sternohyoid, sternothyroid muscles,
  - Thymus,
  - Brachiocephalic veins and the upper half of superior venacava.
- ***Intermediate structures***
  - Internal thoracic vessels,
  - Arch of aorta, Brachiocephalic, left common carotid and subclavian arteries, Left superior intercostal vein,
  - Right and left vagal nerves, Phrenic nerves, cardiac nerves and the superficial part of cardiac plexus
- ***Prevertebral structures***
  - Trachea, oesophagus and thoracic duct,
  - Left recurrent laryngeal nerve,
  - Paratracheal, brachiocephalic and tracheobronchial lymph nodes,
  - Origin of longus colli muscle

Vessels in the Superior Mediastinum

- ***Brachiocephalic veins:*** The right and the left brachiocephalic veins are formed behind the respective sternoclavicular joint by the union of the internal jugular and the subclavian veins. At the level of the inferior border of the first costal cartilage, the two veins unite to form the superior vena cava. Of the two, the left is about twice longer than the right because it has to cross from the left to the right side; it does so anterior to the roots of the three main branches of the aorta. The brachiocephalic veins drain blood from the head, neck and upper limbs.
- ***Arch of aorta:*** Sometimes referred to as the aortic arch (it is preferable to restrict the term aortic arch to the embryologic structures), the arch of aorta is the continuation of the ascending aorta. The arch commences at the level of the sternal angle just behind the second right sternocostal joint. It then arches superiorly, posteriorly and to the left, ascending anterior to the right pulmonary artery and the bifurcation of trachea (Fig. 6.6). Reaching the apex of the arch at the left side of trachea and oesophagus, it passes over the root of the left lung. Then is the descending loop of the arch, which passes posterior to the root of the left lung adjacent to the T4 vertebra. The arch of aorta continues as the descending aorta at the level of the second left sternocostal joint.

The three branches of the arch of aorta are the ***brachiocephalic trunk***, the ***left common carotid artery*** and the ***left subclavian artery***.

- The ***brachiocephalic trunk*** is the first and the largest branch of the arch of aorta. It arises, posterior to the manubrium, from the arch at a point behind the left brachiocephalic vein and anterior to the trachea. It ascends up crossing the trachea and passing superolaterally to reach the right side of trachea and the right sternoclavicular joint. At this point, it divides into the right common carotid and right subclavian arteries.

- The ***left common carotid artery*** is the second branch of the arch. It arises, posterior to the manubrium, from the arch, slightly posterior and to the left of the brachiocephalic trunk. Ascending anterior to the left subclavian artery, it crosses from in front of the trachea to the latter's left. It then enters the neck by passing behind the left sternoclavicular joint.
- The ***left subclavian artery*** is the third branch of the arch. It arises from the posterior aspect of the arch, immediately posterior to the left common carotid artery. Running to the left of trachea through the superior mediastinum it enters the neck by passing behind the left sternocostal joint.

From the inferior surface of the arch of aorta, a fibrous cord passes to the root of the left pulmonary artery. This is the ligamentum arteriosum and is the remnant of the embryonic ductus arteriosus.

Nerves in the Superior Mediastinum

Vagal Nerves (Fig. 6.6)

The ***vagal nerves*** descend through the neck, posterior to the respective common carotid arteries. They then descend into the superior mediastinum behind the respective sternoclavicular joint and brachiocephalic vein (Both these nerves have distribution to thoracic and abdominal structures; hence it is not possible to split the course and distribution to the superior mediastinum alone).

The ***right vagus nerve*** enters into the thorax anterior to the right subclavian artery. At this point, it gives off the right recurrent laryngeal branch, which hooks around the right subclavian artery to ascend up in the groove between the trachea and the oesophagus. This branch reaches the larynx and supplies it. The right vagus nerve then runs through the superior mediastinum on the right aspect of trachea, passing posterior to the right brachiocephalic vein, superior vena cava and root of the right lung. Behind the root of right lung, it divides into many branches which contribute to the right pulmonary plexus. Leaving the pulmonary plexus as a single nerve, it reaches the oesophagus to again break up into many branches which form the oesophageal nerve plexus along with similar branches from the left vagus nerve. Twigs from the right vagus nerve also reach the cardiac plexus.

The left vagus nerve enters into the thorax between the left common carotid artery and the left subclavian artery. It then runs on the left side of the arch of aorta. At the inferior border of the arch, it gives off the left recurrent laryngeal branch. This branch winds around the arch, lateral to the ligamentum arteriosum, and ascends up in the groove between the trachea and the oesophagus, to reach the larynx and supply it. The left vagus nerve passes posterior to the root of the left lung and breaks up into many branches which form the left pulmonary plexus. The nerve then leaves the plexus in a single trunk to the oesophagus. At the oesophagus, it gives out several twigs which join with similar twigs from the right vagus nerve and form the oesophageal nerve plexus.

Phrenic Nerves (Fig. 6.6)

The phrenic nerves supply the diaphragm. Sensory nerve fibres of this nerve form one-third of the total, while motor fibres form two thirds. The phrenic nerves enter into the superior mediastinum between the brachiocephalic veins and the subclavian arteries. They pass anterior to the roots of the corresponding lungs. This is a factor of distinction between the phrenic and the vagus nerves.

The right phrenic nerve, on entering the thoracic cavity, runs on the right brachiocephalic vein, gradually moving anteriorwards, thus diverging away from the right vagus nerve. It then passes over the superior vena cava and the pericardium over the right atrium. Passing anterior to the

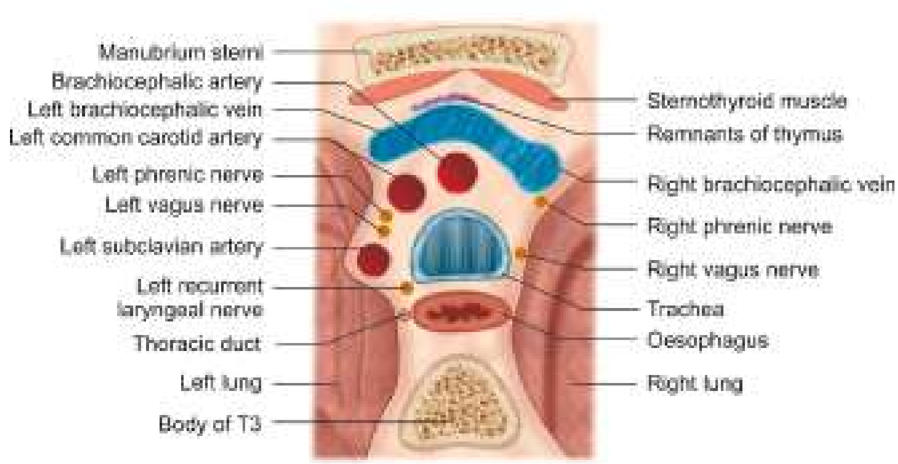


Fig. 6.6: Transverse section through the superior mediastinum just above the summit of the arch of aorta to show relations of trachea

root of the right lung, it runs on the right side of the inferior vena cava to reach the diaphragm and supply it.

The left phrenic nerve, on entering the thoracic cavity, runs on the left surface of the arch of aorta and at this point is anterior to the left vagus nerve. It then passes over the left superior intercostal vein and reaches the root of the left lung. Passing anterior to this root, it descends on the pericardium covering the left atrium and left ventricle, to reach the diaphragm.

Both the phrenic nerves actually pierce the diaphragm and ramify into many branches on the inferior surface of the diaphragm.

INFERIOR MEDIASTINUM

Anterior Mediastinum

This is the smallest division of the mediastinum and the most anterior of the the inferior mediastinal portions. It is the space between the body of sternum anteriorly and the pericardium posteriorly. It is continuous superiorly with the superior mediastinum and is inferiorly closed by the diaphragm.

Contents

The superior and inferior sternopericardial ligaments;

- Superior and inferior sternopericardial ligaments;
- Retrosternal lymphnodes and few lymphatics; and
- Mediastinal branches of inetrnal thoracic artery.

The sternopericardial ligaments are strands of loose connective tissue connecting the posterior aspect of the body of sternum and the anterior aspect of the fibrous pericardium.

In infants and young children, the anterior mediastinum contains the thymus, which is large and extends till this level.

Thymus

The thymus is a lymphoid organ. It is located in the lower part of the neck and the anterior part of the mediastinum. Lying posterior to the manubrium as a flat gland, it may extend to the anterior mediastinum (part of the inferior mediastinum) in front of the fibrous pericardium. Though considerably large in children, the thymus undergoes involution after puberty. Fat replaces thymic tissue and so it is customary to say, only thymic remnants are found in the adults. As a lymphoid organ, it receives abundant blood supply from the anterior intercostal and anterior mediastinal branches of the internal thoracic arteries. Its veins drain into the internal thoracic, inferior thyroid and left brachiocephalic veins. The lymphatics from the thymus drain into the parasternal, brachiocephalic and tracheobronchial lymph nodes.

Middle Mediastinum

It is the broadest part of the inferior mediastinum occupied mainly by the heart.

Contents

The Pericardium enclosing the heart, the ascending aorta, the pulmonary trunk dividing into right and left pulmonary arteries, the four pulmonary veins, the lower part of SVC, the arch of azygos vein, the bifurcation of trachea, the right and left bronchi, the right and left phrenic nerves, the deep cardiac plexus of nerves and the inferior tracheo-bronchial lymphnodes.

Posterior Mediastinum

The posterior mediastinum is the posterior of the inferior mediastinal portions and is bounded

- ***Anteriorly:*** By bifurcation of trachea, pulmonary vessels,pericardium and posterior part of the upper surface of the diaphragm,
- ***Posteriorly:*** By bodies of lower eight thoracic vertebrae,
- ***Above:*** By the imaginary plane passing through the sternal angle and T4 vertebra,
- ***Below:*** By the diaphragm and
- ***On each side:*** By the mediastinal pleura

Contents

- Descending thoracic aorta, azygos and hemiazygos veins
- Right and left sympathetic chains, splanchnic nerves, right and left vagal nerves
- Oesophagus, thoracic duct
- Posterior mediastinal lymph nodes

The sympathetic chains and the splanchnic nerves are not included in the contents of the posterior mediastinum by some authorities, because, they lie lateral to the bodies of the vertebrae and so, technically are not within the mediastinal space.

Vessels in the Posterior Mediastinum

Descending thoracic aorta: It is the continuation of the arch of aorta. Commencing on the left side of the body of T4 vertebra, it descends in the posterior mediastinum on the left side of the bodies of T5 to T12 vertebrae. As it descends, it gradually moves to the midline (from left) and so, displaces the oesophagus to the right side. It is posterior to the root of left lung, pericardium and oesophagus. It enters the abdomen through the aortic opening in the diaphragm and becomes the abdominal aorta. The azygos vein and the thoracic duct ascend up into the thorax through the same opening and run upwards on the right side of the descending aorta.

The branches of the descending aorta can be grouped into three: (1) ***Unpaired visceral branches*** arising on the anterior median plane (and supplying gut or its derivatives); (2) ***Paired visceral branches*** arising from the lateral aspect (and usually supplying viscera other than those of gastrointestinal tract); and (3) ***Paired parietal branches*** arising on the posterolateral aspect.

The oesophageal arteries, usually two or three in number, are the unpaired anterior visceral branches. They supply the oesophagus. The paired visceral branches of the lateral plane are the bronchial arteries. Normally, two left bronchial arteries arise from the aorta; one or two right bronchial arteries arise from the third posterior intercostal artery. The paired parietal branches are represented by the nine posterior intercostal arteries and the subcostal arteries.

Three other sets of arteries can be added to the above-mentioned list: (1) ***Pericardial arteries:*** These are small branches arising in the anterior midline of the descending aorta; being unpaired, they reach out to the pericardium and supply it; (2) ***Mediastinal arteries:*** These are also small, anterior midline branches which supply the tissues of the posterior mediastinum including the lymph nodes; (3) ***Superior phrenic arteries:*** These are a pair of parietal branches which arise anterolaterally and supply the superior surface of the diaphragm; they anastomose with the musculophrenic and pericardiophrenic arteries.

Azygos and hemiazygos veins: The azygos (Greek. azygos=unpaired) system of veins can be described as a collateral pathway between the superior vena cava and the inferior vena cava. It drains the back, thoracoabdominal walls and the mediastinal viscera. There is much variation in the origin, course and tributaries of the system.

The azygos vein is formed by the union of the lumbar azygos, right subcostal and right ascending lumbar veins. It ascends in the posterior mediastinum, on the right side, close to the bodies of the T12 to T5 vertebrae. Reaching the posterior aspect of the root of right lung, it arches over the root to join the superior vena cava.

Nerves in the Posterior Mediastinum

The sympathetic trunks and their associated ganglia are the nerves and nervous tissue seen in the posterior mediastinum. Each thoracic sympathetic trunk is continuous above with the cervical sympathetic trunk and below with the lumbar sympathetic trunk. It lies against the heads of ribs in the upper part, the costovertebral joints in the middle part and the sides of the vertebral bodies in the lower part. Arising from the sympathetic trunk are the greater, lesser and least splanchnic nerves (part of the abdominopelvic splanchnic nerve group); these nerves enter into the abdominal cavity by piercing through the corresponding crus of the diaphragm.

Clinical Correlation

- Patients may present with mass in the mediastinum. 30% of mediastinal masses are congenital mediastinal cysts, with the cysts being any of the mediastinal contents. The common cysts in the order of frequency are bronchogenic, thymic, pericardial, pleural, oesophageal, thoracic duct cysts.
- Parathyroid adenoma may present as mediastinal mass in 3% of cases.
- Cervical Mediastinoscopy is done to visualise the lymph nodes and for biopsy of the same.

The thoracic cavity, as already noted, is divided into three compartments. These are the two (right and left) pulmonary cavities and the central mediastinum.

The pulmonary cavities are bilateral (right and left), contain structures of the respiratory system and occupy most of the thoracic cavity. Each pulmonary cavity is lined by a pleural membrane that also gets reflected to cover the lung which occupies the pulmonary cavity.

PLEURA

Each lung is enclosed in a pleural sac, covered by pleura.

To understand the relationship of the lung to its pleura, the student may well imagine to push his/her fist into a balloon. The balloon should not be 'completely filled' with air, but should be a little 'loose' and underinflated. When the fist is pushed into such a balloon (Fig. 6.7), it can be seen that a portion of the balloon drapes around and covers the fist; another portion is outer and close to the wrist (which now appears like a root for the hand that has gone into the balloon) the two portions become continuous with each other. If the balloon-fist situation is replaced with the pleura-lung situation, the portion covering the fist (and closely approximated to it) is the ***visceral layer of the pleura***; the portion outer is the ***parietal layer of the pleura***. The place where the two layers become continuous (the ***wrist or root of hand***) is the root of lung; and the fist is the lung per se. A small space occurs between the visceral and parietal layers and is the pleural cavity. It can also be seen that the lung is outside the pleural cavity, but surrounded and covered by the ***pleural sac*** (the fist is not inside the balloon but covered by it; this is invagination of the lung into the pleural sac). The pleural cavity is maintained at a negative pressure by the inward elastic recoil of the lung and the outward pull of the chest wall.

The right and left pleural sacs form separate compartments and are approximated to each other only behind the upper half of the sternal body. The sacs are also close to each other behind the oesophagus at the mid thoracic level. The region between them is the mediastinum (or the interpleural sac).

From the above description, it can be understood that each lung is enclosed in a pleural sac. Each pleural sac consists of two layers, namely the ***visceral*** and ***the parietal layers***. The two layers are continuous with each other (Fig. 6.8). The visceral layer covers the lung; the parietal layer lines the pulmonary cavity.

VISCERAL PLEURA

The visceral (or pulmonary) pleura is inseparably adherent to the lung over all its surfaces, including the fissures, except at the hilum of the lung and a line descending from the hilum, which marks the attachment of pulmonary

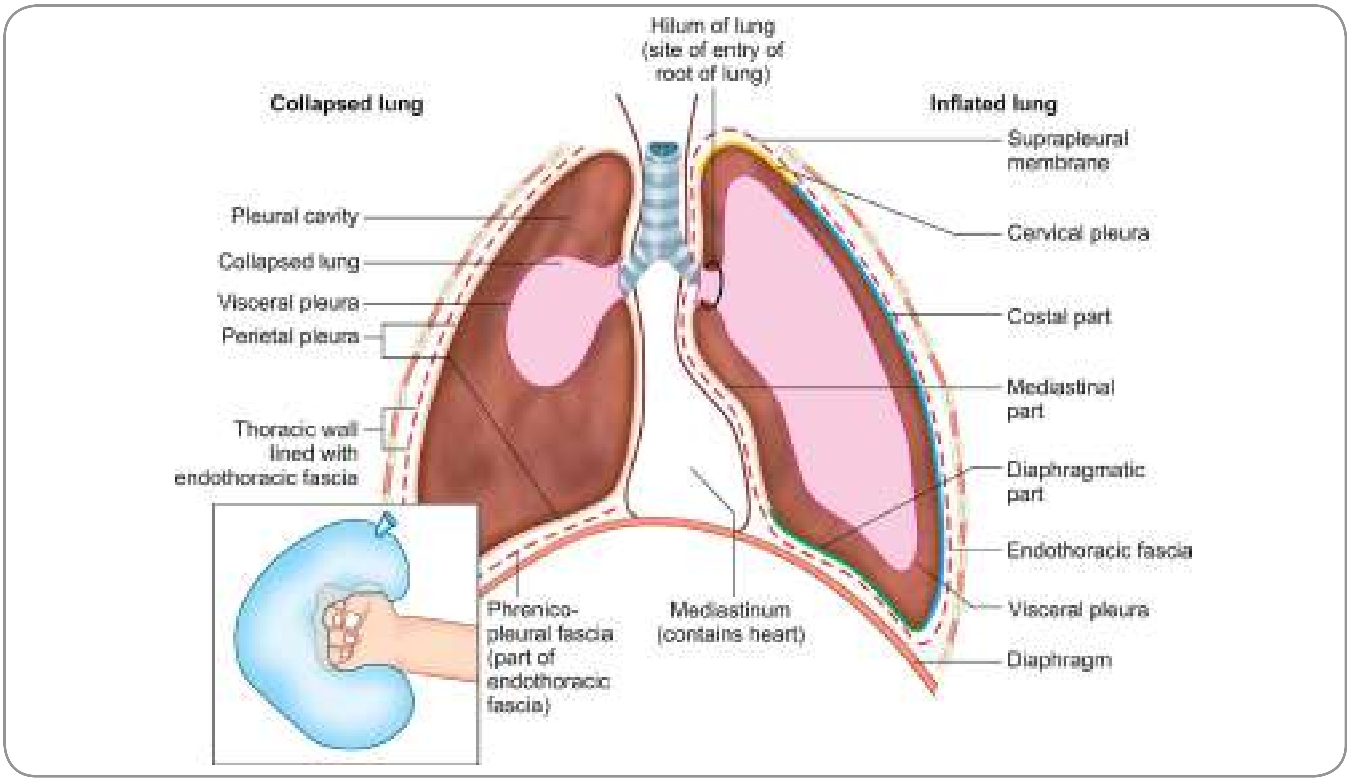


Fig. 6.7: The concept of insinuating a 'fist' into a balloon likened to the invagination of pleural sac by the lungs

ligament. It cannot be usually peeled off the lung tissue and gives the lung a smooth shiny outer surface. The slipperiness provided by the visceral pleura makes the lung move friction free on the parietal pleura. At the hilum of the lung, the visceral layer becomes continuous with the parietal layer. Various structures enter in and come out of the lung at the hilum. The folding of the pleura at this point provides a sheath for these structures and the entire 'bunch' appears like a stalk or pedicle (called the ***root*** because it appears to provide anchorage) for the lung. The lung can be said to be suspended within the pleural cavity by the root.

PARIETAL PLEURA

The parietal pleura lines the corresponding half of the thoracic cavity and thereby covers the diaphragm, the thoracic wall and the mediastinum. It is thicker than the visceral pleura. During surgical procedures, it had been possible to separate this layer from the underlying tissue that it covers. Different regions of the parietal pleura are named according to the different structures they line, namely costovertebral pleura, diaphragmatic pleura, cervical pleura and mediastinal pleura (Figs 6.8 and 6.9).

- The ***costovertebral pleura*** (or costal pleura) lines the thoracic wall comprising the inner surface of sternum, ribs, intercostal spaces and the sides of the vertebral bodies, but is separated from the above structures by a loosely attached layer of areolar tissue called the ***endothoracic fascia***.

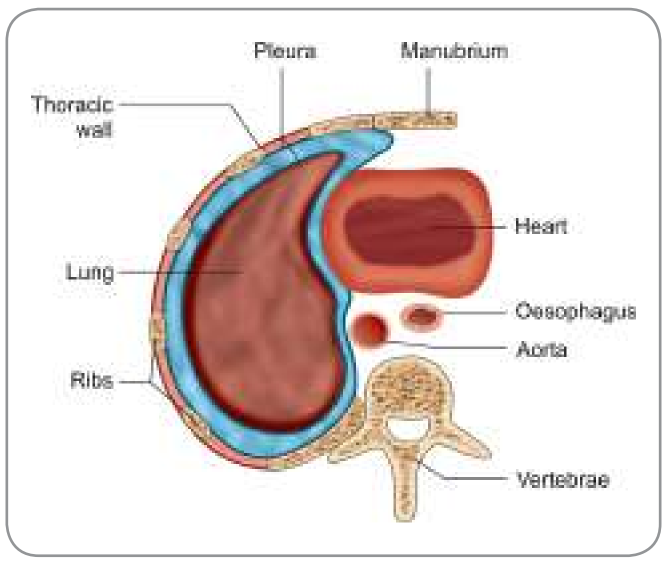


Fig. 6.8: Schematic transverse section through the left half of the thorax to show some features of the pleura

- The ***diaphragmatic pleura*** covers the thoracic surface of the corresponding part of the diaphragm and laterally is continuous with the costovertebral pleura along the costodiaphragmatic line. Medially, it is continuous with the mediastinal pleura along the

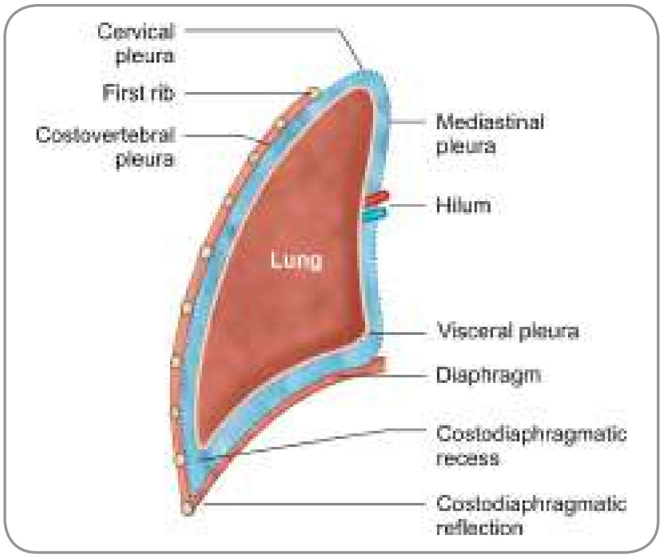


Fig. 6.9: Schematic coronal section through one half of the thorax to show some features of the pleura

attachment of the fibrous pericardium to the central tendon of the diaphragm. A thin layer of areolar tissue (much thinner than the endothoracic fascia and more elastic) intervenes between the diaphragmatic pleura and the muscle fibres of diaphragm; this is called ***phrenicopleural fascia***.

- The ***cervical pleura*** extends from the inner border of the 1st rib to cover the apex of the lung, and then passes downwards and medially to continue with the mediastinal pleura. It forms a cup like dome, called the ***pleural cupola***, over the apex; the summit of this dome reaches (2 to 3 cm) higher than the level of the medial third of the clavicle at the level of the neck of the first rib. The cervical pleura is covered externally by the supra pleural membrane (Sibson's fascia) and all structures related to the apex of the lung are superficial to the supra pleural membrane. The supra pleural membrane is a musculo fascial expansion, derived from the scalenus minimus muscle and endothoracic fascia. It extends between the tip of the transverse process of the 7th cervical vertebra to the inner border of the 1st rib. Medially, it is continuous with the pretracheal fascia by the side of the trachea.
- The ***mediastinal pleura*** is the lateral boundary of the mediastinum and forms a continuous surface above the hilum of the lung from sternum to vertebral column (Fig. 6.9). At the hilum of the lung, it turns laterally to form a tube that encloses the hilar structures and is continuous with the pulmonary pleura. Below the hilum, the mediastinal pleura forms a bilaminar fold called ***pulmonary ligament*** which extends between the oesophagus and the mediastinal surface of the lung, where it is continuous with parietal pleura. The pulmonary ligament contains some loose areolar tissue and lymphatics and serves as a dead space for the expansion of the inferior pulmonary vein. Superiorly, the mediastinal pleura is continuous with the cervical pleura, anteriorly and posteriorly with the costal pleura and inferiorly with the diaphragmatic pleura.

Lines of Pleural Reflection (Fig. 6.10)

The line along which the parietal pleura changes direction from one wall of the thoracic cavity to another is the line of pleural reflection. There are three lines of pleural reflection, namely the ***sternal***, ***costal*** and ***diaphragmatic lines***. These lines determine the extent of the pulmonary cavities (Figs 6.11 and 6.12).

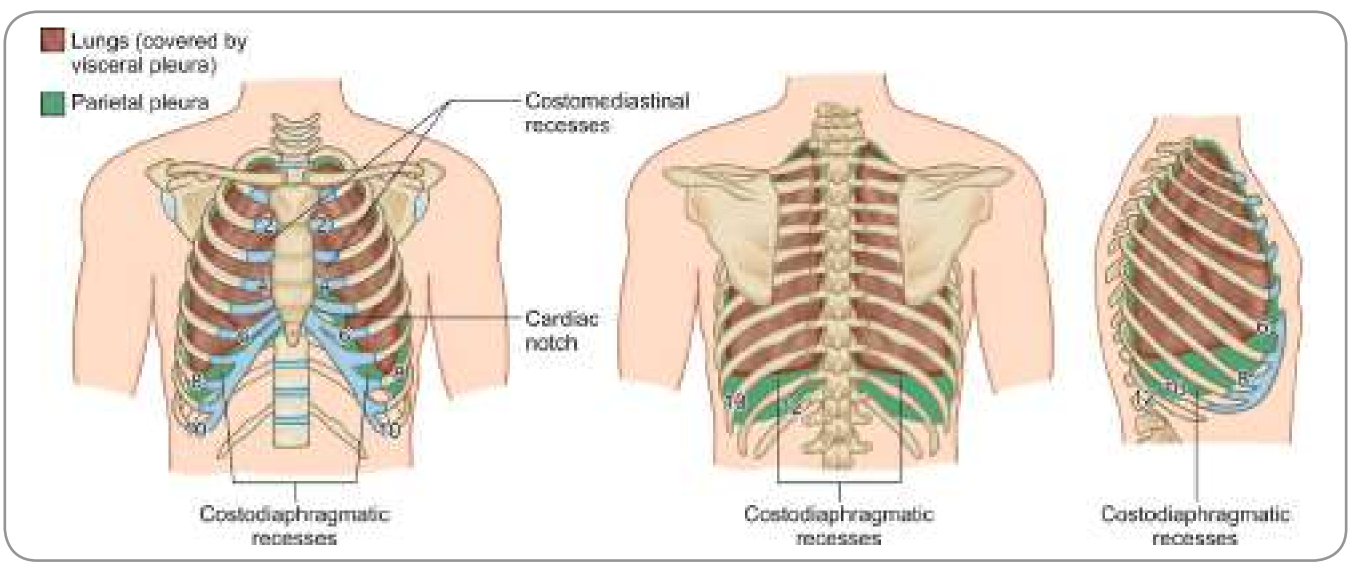


Fig. 6.10: Lines of pleural reflection; pleural recesses are also shown

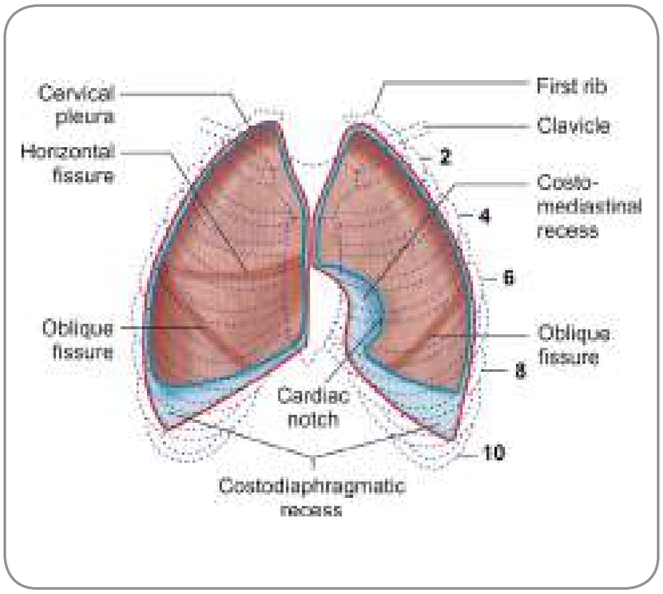


Fig. 6.11: Scheme to show the relationship of lines of pleural reflection (red line) and of the lungs (blue line) to the skeleton of the thorax

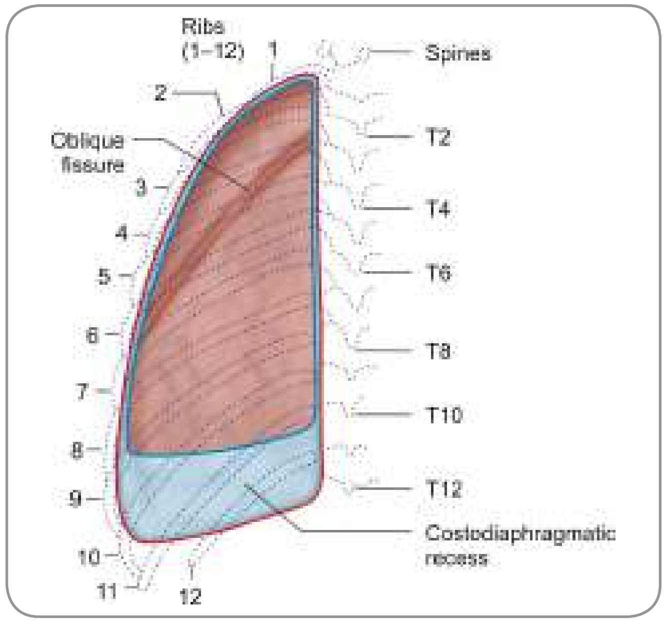


Fig. 6.12: Projection of the pleura (red line) and lung (blue line) on the back of the thorax

Sternal Lines of Pleural Reflection

The right and the left sternal lines are not symmetrical or mirror images of each other. The 'centrally placed' heart is turned and deviated to the left; so the left sternal line is deflected more. The sternal lines occur at the line where the costal pleura becomes continuous with the mediastinal pleura on the anterior aspect. Both the right and left lines start at the cupola (Fig. 6.26), run inferomedially and pass behind the respective sternoclavicular joints to meet at the midline at the level of the sternal angle posterior to the sternum. From this point, both the lines descend in contact with each other till the level of the 4th costal cartilage. Below the 4th costal cartilage, both lines move away from each other.

The right sternal line proceeds down the midline till the posterior aspect of the xiphoid process, which is the level of the sixth costal cartilage. Here, it turns laterally and continues as the right costal line of pleural reflection.

The left sternal line, at the level of the 4th costal cartilage, turns laterally and descends inferolaterally to reach the lateral border of sternum at the middle of the fourth intercostal space. It continues to descend inferolaterally to reach the 6th costal cartilage on the midclavicular line. This deviation causes a shallow notch, usually referred to as the ***cardiac notch***. This is the area where the pericardium is in direct contact with the anterior thoracic wall and is called the ***pericardial bare area***.

Costal Lines of Pleural Reflection

These occur along lines where the costal pleura becomes continuous with diaphragmatic pleura on the inferior aspect. The two sternal lines continue into the costal lines.

The right costal line starts at the point where the right sternal line turns laterally on the midline at the level of the 6th costal cartilage. It runs inferolaterally, laterally, posteriorly and medially in that order as it can be traced from the anterior midline to the level of the neck of the 12th rib around the thoracic wall. It crosses the 8th rib in the midclavicular line and the 10th rib in the midaxillary line. The left costal line commences at the 6th costal cartilage on the midclavicular line and takes a similar course as that of the right costal line. It also runs inferolaterally, laterally, posteriorly and medially to reach the neck of the 12th rib. This line also crosses the 8th rib in the midclavicular line and the 10th rib in the midaxillary line. Both the costal lines become continuous with the vertebral lines of pleural reflection on the posterior aspect at the level of the necks of the 12th ribs.

Vertebral Lines of Pleural Reflection

These are lines where the costal pleura becomes continuous with the mediastinal pleura on the posterior aspect. These lines are not sharp like the other lines of pleural reflection since the transition is very gradual. Both the right and the left lines run parallel to the vertebral column, in the paravertebral planes on either side, from T1 to T12 vertebrae.

The lines along which one surface of the lung becomes another surface are to be remembered here. Such lines will fix the extent of the lungs. These lines will also determine the extent of the visceral pleura.

The space between corresponding lines of parietal and visceral pleural reflections will indicate the pleural cavity.

It can well be seen that, at certain locations, the parietal and visceral pleurae are much separated from each other, resulting in the formation of pleural recesses.

PLEURAL RECESSES

The pleural recesses are slightly dilated spaces of the pleural cavity, the dilatations occurring due to separation of the visceral and the parietal pleurae. The lungs do not completely occupy the pulmonary cavities. In places where there are gaps, the parietal and the visceral pleurae are separated from each other and give rise to the pleural recesses.

On the inferior aspect, the pleural cavity extends beyond the inferior border of the lung and there exists a potential space between the ***pleural sac*** and the lower border of the corresponding lung. This is specially true during expiration and quiet respiration, when the inferior margin of the lung does not reach the ***pleural reflection*** and the peripheral diaphragmatic pleura may come in contact with the lowermost portions of the costal pleura. The lower limit of the pleura corresponds to the 8th, 10th and 12th ribs in the mid-clavicular, mid-axillary and scapular lines respectively whereas, the lower border of the lung corresponds to the 6th, 8th and 10th ribs in the respective three lines. The costal and the diaphragmatic pleurae are thus separated by a narrow slit like space called the ***costo-diaphragmatic recess (Figs 6.11 and 6.12)***. This actually is a pleura lined gutter around the upward convexity of the diaphragm inside the thoracic wall and is 'potential' because the space can widen to accommodate fluid. The recess is widest in the mid axillary line in quiet respiration, where the lower limit of the lung is 5 cm above the pleural limit. During deep inspiration, the inferior borders of the lungs move farther into the costodiaphragmatic recesses than during quiet inspiration and expiration.

Similarly, a ***costomediastinal recess*** (Fig. 6.11 and 6.12) exists behind the sternum and the costal cartilages, between the thin anterior margin of the lung and the pleural reflection there. The left costomediastinal recess is slightly larger than the right because the cardiac notch of the lung is deeper than the corresponding notch of the left pleural sac.

NERVE SUPPLY OF PLEURA

The parietal and the visceral pleurae develop from the somatopleural and sphlanchnopleural layers of the lateral plate mesoderm respectively. So, the parietal pleura is supplied by the somatic nerves and is sensitive to pain like that of the nerve supply of the parietes (wall structures) of the thorax. The costal and the peripheral parts of the diaphragmatic pleura are supplied by the intercostal nerves whereas the mediastinal and the central parts of diaphragmatic pleura are supplied by the phrenic nerves

The visceral pleura is supplied by autonomic nerves (T2–5) like that of the lung and is insensitive to pain.

BLOOD SUPPLY AND LYMPHATIC DRAINAGE OF PLEURA

The vascular supply and lymphatic drainage of the parietal pleura is as that of the parietes of the thorax and of the visceral pleura is as that of the lungs.

Clinical Correlation

- The first pair of ribs and the superior thoracic aperture are sloping anteroinferiorly. This causes the cervical pleura (and the apex of the lung) to project into the neck. As a result, the cervical pleura (and the apex of the lung) may be injured in wounds of the neck and lead to pneumothorax.
- The cervical pleura (and the apex of the lung) projects to a higher level into the neck in children due to shortness of neck.
- In three important regions, the pleural sac descends inferior to the costal margin and thus overlaps the external dimensions of the abdominal cavity. These are: (1) right part of infrasternal angle, (2) and (3) the right and left costovertebral angles. In these places, the pleura may be inadvertently injured during surgical procedures.
- Inflammation of the pleura is known as ***pleuritis or pleurisy***. It may be associated with pleural effusion or may be dry. In dry pleurisy, the surfaces of both the visceral and parietal pleurae become rough leading to ***friction rub***, which can be heard during auscultation. The condition is associated with chest pain. The pain may be referred to the anterolateral abdominal wall if the costal and peripheral parts of the pleura are affected (because of the intercostal nerve supply) or may be referred to neck, if the central diaphragmatic or mediastinal pleurae are affected (because of the phrenic nerve supply).
- Accumulation of significant quantity of fluid will lead to ***pleural effusion*** which is associated with disappearance of friction rub. The nature of the accumulated fluid may be serous (hydrothorax), purulent (empyema/pyothorax), blood (haemothorax) or chylous (chylothorax-due to rupture of thoracic duct). The effusion is first visible in the ***region of the costodiaphragmatic recess*** as it is the most dependent part of the pleural cavity. It is seen as a radio-opaque shadow with a fluid line in the chest X-ray.
- Because of the negative pressure in the pleural cavity, any opening created in the thoracic wall (e.g. by injury) sucks air into the pleural cavity. Entry of air into the pleural cavity (***open pneumothorax***) leads to collapse of the lung (with resultant loss of function). In 'open pneumothorax', the pleural cavity is exposed to the atmosphere, with sucking in of air and blowing out. A broken rib may also injure the underlying lung and air can then enter the pleural cavity through the lung. Once the opening is closed, the air in the pleural cavity is gradually absorbed and the lung expands once more. Entry of air (or collection of fluid in large amounts) in one pleural cavity can also exert pressure on the mediastinum and can push it to the opposite side.

contd…

Clinical Correlation *contd...*

- In cases of open pneumothorax, air can also pass into subcutaneous tissues. This is called ***surgical emphysema***. This air can spread and can even enter the neck and head.
- When the opening of the visceral pleura is *valvular*, it allows air entry into the pleural sac only during inspiration and prevents air exit during expiration. This leads to a rapid increase of the volume of air in the pleural cavity, followed by lung collapse and suffocation. This condition is called ***tension pneumothorax*** and is a surgical emergency needing immediate decompression.
- ***Paracentesis thoracis:*** Fluid in the pleural cavity can be aspirated by passing a needle into an intercostal space (usually the 6th) in the midaxillary line. The needle has to be inserted through the lower part of the space to avoid injury to the neurovascular bundle present along the upper border of the space. The needle passed into one of the lower intercostal spaces, in the midaxillary line, will penetrate skin and fascia, the serratus anterior muscle, the intercostal muscles (three layers) and the parietal pleura to reach the pleural cavity. The needle should not be inserted below the 9th intercostal space, so as to avoid injury to the liver in the right side and spleen in the left side.

SURFACE PROJECTION OF PLEURA

Surface projection of the pleura follow the lines of pleural reflection.

Right Costomediastinal Reflection

a. A point on the right sternoclavicular joint
b. A point in the middle of the sternal angle
c. A point on the xiphisternal joint

The line joining points a and b slopes downward and medially, and rest of the line between b and c runs almost vertically downwards.

Left Costomediastinal Reflection

a. A point on the left sternoclavicular joint
b. A point at the middle of the sternal angle
c. A point in the midline at the level of fourth costal cartilage
d. A point on the left side of the xiphisternal joint

The line joining points a and b passes downward and medially, and between points b and c passes vertically downward.From the level of the fourth costal cartilage at point c, the line deviates to the left to reach the lateral border of sternum and follows the latter until it meets the point d.

Costodiaphragmatic Reflection

a. A point at the middle of the xiphisternal joint (right side), or at the left end of the xiphisternal joint (left side)
b. A point over the eighth rib in the mid clavicular line
c. A point over the tenth rib in the mid axillary line
d. A point about 2 cm lateral to the twelfth thoracic spine.

Draw a line joining the above points.It describes a curve which presents a downward convexity with its summit lying in the mid axillary line.The costodiaphragmatic reflection on the right side crosses the right costoxiphoid and costovertebral angles, but on the left side it crosses the left costovertebral angle only.

Costovertebral Reflection

On each side the posterior limit of the pleural sac is represented by a vertical line by joining the following points:

a. A point about 2 cm lateral to the seventh cervical spine
b. A point about 2 cm lateral to the twelfth thoracic spine.

Cervical Pleura

a. A point at the sternoclavicular joint
b. A point on the clavicle at its junction of the medial one third and lateral two thirds.
c. A point about 2.5 above the clavicle and midway between the points a and b.

A line joining the above points describes a convexity towards the root of the neck (Fig. 6.21).

TRACHEA

The trachea is a wide tube lying in the midline, in the lower part of the neck and in the superior mediastinum of the thorax. It is about 10–11 cm long. The trachea enters the thorax through its superior aperture. Its upper end is continuous with the lower end of the larynx. The junction lies opposite the lower part of the body of the sixth cervical vertebra. At its lower end, the trachea ends by dividing into the right and left principal bronchi. The level of bifurcation corresponds to the lower border of the manubrium sterni or to the lower border of the fourth thoracic vertebra (the plane of sternal angle and lower limit of superior mediastinum) and is slightly deviated to the right. The lumen of the trachea is kept patent because of the presence of a series of cartilaginous rings in its wall. A triangular process known as ***carina*** is present in the last ring which hooks upwards from the lower margin and surrounds the commencement of the two bronchi. The mucous membrane in the region of carina is one of the most sensitive areas and is associated with cough reflex, which can act as a defence mechanism in expulsion of foreign bodies. The rings are deficient posteriorly and filled with trachealis muscle. Hence, the posterior part of the wall of the trachea is flat while the rest of it is rounded. The transverse diameter of the lumen in live adults measures about 12 mm which increases in cadavers because of the relaxation of the posterior smooth muscle.

In the first postnatal year, the tracheal diameter does not exceed 4 mm, while during later childhood the diameter corresponds to child's age in years. This knowledge is important for selection of the appropriate size of the tube during tracheal intubation by anaesthetists.

RELATIONS OF THE TRACHEA IN THE THORAX

The trachea is related to a large number of structures in the neck and in the thorax. The relations in the thorax are as follows (Fig. 6.13):

Anteriorly

- The trachea is covered by skin, superficial and deep fascia, and by the ***manubrium sterni*** (Fig. 6.6).
- The right and left sternohyoid and sternothyroid muscles (which arise from the posterior aspect of the manubrium sterni) overlap the part of the trachea near the inlet of the thorax along with the thymic remnants and inferior thyroid vein.
- The ***arch of the aorta*** lies in close contact with the trachea near its lower end. It is first anterior to the trachea and then on its left side (Fig. 6.13).
- The ***brachiocephalic trunk*** is at first in front of the trachea, but as it passes upwards it reaches the right side of the trachea.
- The ***left common carotid artery*** is at first in front of the trachea. As it passes upwards it reaches the left side of the trachea.
- The ***left brachiocephalic vein*** crosses in front of the trachea just above the arch of the aorta.
- The ***deep cardiac plexus*** and some lymph nodes are also anterior to the trachea.

Posteriorly

The trachea is related to the ***oesophagus*** that runs vertically behind it, and separates it from the bodies of the upper four thoracic vertebrae.

Laterally

- To the ***right*** are:
  - The right lung and pleura,
  - The right brachiocephalic vein, superior venacava, azygos vein, and
  - The right vagus nerve.
- To the ***left*** are;
  - The arch of aorta, the left common carotid artery and the left subclavian artery (which arises from the part of the arch of the aorta that lies to the left of the trachea).
  - The left recurrent laryngeal nerve is at first situated between the trachea and aortic arch and then lies in the groove between the trachea and oesophagus.

Histology

The wall of the trachea is made up of hyaline cartilage anteriorly, completed posteriorly by smooth muscle. The lumen is lined by mucous membrane consisting of lining epithelium and underlying connective tissue. The lining epithelium is made of pseudostratified ciliated columnar epithelial cells interspersed by goblet cells, basal cells and lymphocytes deeper to them. The sub epithelial connective tissue contains numerous elastic fibres, serous glands and mucous glands. Numerous lymphoid tissue aggregations are also present within the connective tissue layer. The serous glands keep the epithelium moist, mucous glands provide a protective layer of mucus for trapping of dust particles.

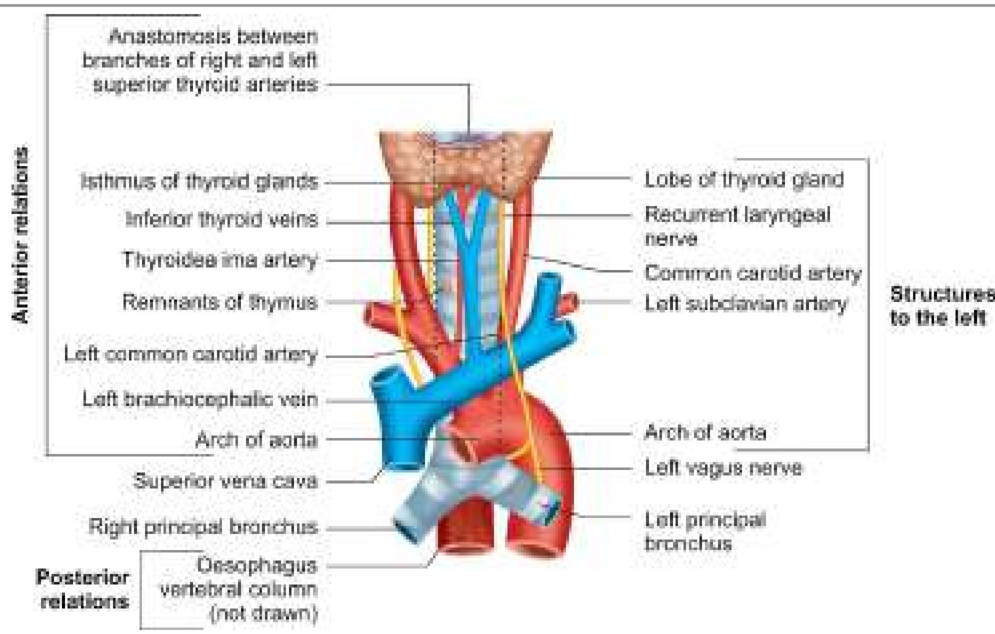
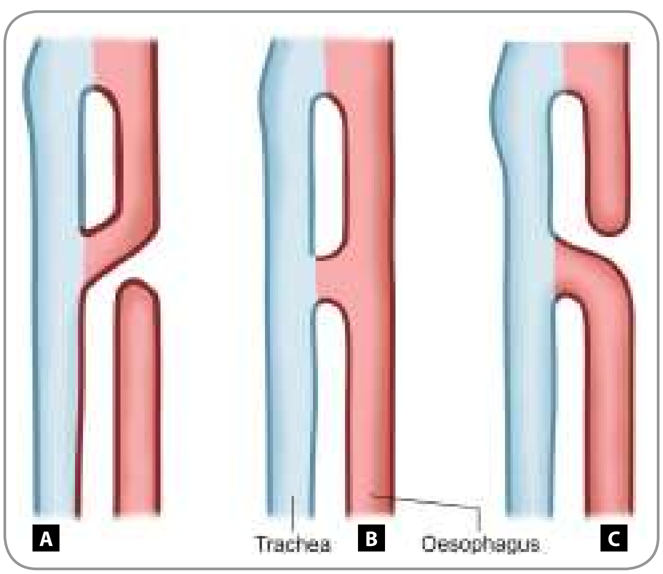


Fig. 6.13: Relations of the trachea as seen from the front

Clinical Correlation

- The trachea can be palpated in the suprasternal notch. Deviation of the trachea from the midline could indicate a mediastinal shift.
- ***Tracheostomy:*** This is a procedure to create an artificial opening in the trachea in the neck. It is used to provide an alternative route for supply of air to the lungs when there is obstruction in the larynx or upper end of the trachea. The 2nd and 3rd (and sometimes the 4th) tracheal rings are cut and a tube is inserted into the trachea through the opening.
- At ***bronchoscopy***, in the distal end of trachea near its bifurcation, the carina is visible as a concave spur, which serves as a guide for the physician.
- ***Stenosis of the trachea:*** Stenosis of the trachea may be caused by external pressure. The pressure may be due to
  - An enlarged thyroid gland (e.g. in carcinoma) or enlarged lymph nodes in the region
  - ***An aortic aneurysm*** or by an abnormally located aortic arch.
- Stenosis can also be produced by fibrosis of the wall of the trachea and this may occur as an after effect of tracheostomy.
- The lumen of the trachea can also be obstructed by a foreign body or by a tumour.
- ***Congenital malformations of the trachea***
  - Tracheo-oesophageal fistulae (Figs 6.14A to C).
  - Diverticulae and accessory bronchi may be arising from the trachea. The accessory bronchi may be blind, may supply an accessory lobe, or may replace a normal segmental bronchus.
  - Rarely, the trachea may be absent.
- ***Tracheal tug:*** This is a physical sign often present in cases of aortic aneurysm. To elicit the sign, the examiner stands behind the patient and places his fingers just below the cricoid cartilage. The patient is asked to swallow. This raises the cricoid cartilage that is retained in this position by the fingers. The trachea is now stretched. Pulsations of an aneurysm may then be transmitted through the trachea to the fingers of the examiner.



Figs 6.14A to C: Three varieties of tracheo-oesophageal fistula

BRONCHI

At its lower end, the trachea divides into the right and left ***principal bronchi***. Each principal bronchus begins opposite the lower border of the body of the fourth thoracic vertebra. It passes downwards and laterally to enter the corresponding lung, where each subdivides into successive generations of smaller bronchi and finally reaches the lung units via terminal respiratory bronchioles. Each principal bronchus consists of extrapulmonary and intrapulmonary parts. Within the lungs, the bronchi have a constant branching pattern.

RIGHT BRONCHUS

The ***right principal bronchus*** is wider, shorter and more vertical than the left bronchus. It is more vertical because trachea usually deviates to the right at its bifurcation, hence a foreign body in the trachea is usually aspirated more to the right lung. It is about 2.5 cm (1 inch) long and enters the lung opposite the fifth thoracic vertebra. This part of the bronchus between its commencement and entry into lung is called the extrapulmonary part.

On reaching the hilum of the right lung, the right principal bronchus gives off a superior lobar bronchus to the superior lobe of the lung (otherwise called the ***eparterial bronchus*** as it passes above the pulmonary artery). It then enters the hilum of the lung, descends for a short distance before dividing into the middle and inferior lobar bronchi (which supply the middle and inferior lobes, respectively, of the right lung). Hence, the right principal bronchus ends by dividing into three lobar bronchi (called the ***secondary bronchii***). Each secondary bronchus subdivides into several segmental or tertiary bronchii, each of which supplies a bronchopulmonary segment. A segmental bronchus may branch 6–18 times to produce 50-70 respiratory bronchioles, which merge with the alveolar sacs and terminate into alveoli. The intrapulmonary bronchi upto the beginning of the respiratory bronchioles are collectively known as the ***conducting part of the lung***.

The ***left principal bronchus*** is longer, narrower and more oblique than right bronchus. The extrapulmonary part is approximately 5 cm in length. Passing to the left, inferior to the aortic arch, it crosses anterior to the oesophagus, thoracic duct and descending aorta.It enters the hilum of the lung opposite the sixth thoracic vertebra and then ends by dividing into two lobar bronchi, superior and inferior, corresponding to the lobes of the left lung. The further divisions of the bronchii are as that in the right side.

All those bronchi which pass below the pulmonary arteries, namely, the right middle and inferior lobar bronchi and the left superior and inferior lobar bronchi are hyparterial. However, this term is generally restricted to the bronchus on the right side that passes below the

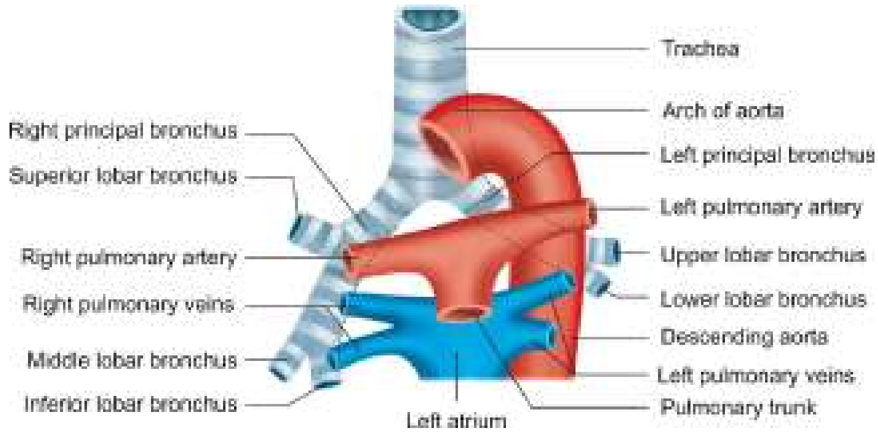


Fig. 6.15: Diagram showing the right and left principal bronchi and their relations

pulmonary artery (bronchus distal to the branching away of the superior lobar bronchus which is eparterial). It should be remembered that the terms ***eparterial*** and ***hyparterial*** are now obsolete.

Relations of the Right Principal Bronchus (Fig. 6.15)

- The ***azygos vein*** lies just above the bronchus (near its origin) as the former arches forwards to join the superior vena cava.
- The ***right pulmonary artery*** is first inferior to the bronchus. It crosses in front of the bronchus, below the origin of the superior lobar bronchus. Thereafter, on reaching the hilum of the lung, the artery passes between the superior lobar bronchus and the continuation of the principal bronchus (Fig. 6.16).
- The lower part of the right principal bronchus is also covered by the upper right pulmonary vein.

Relations of the Left Principal Bronchus (Fig. 6.15)

- The ***arch of the aorta*** lies above the left bronchus. The ***descending aorta*** passes behind it.

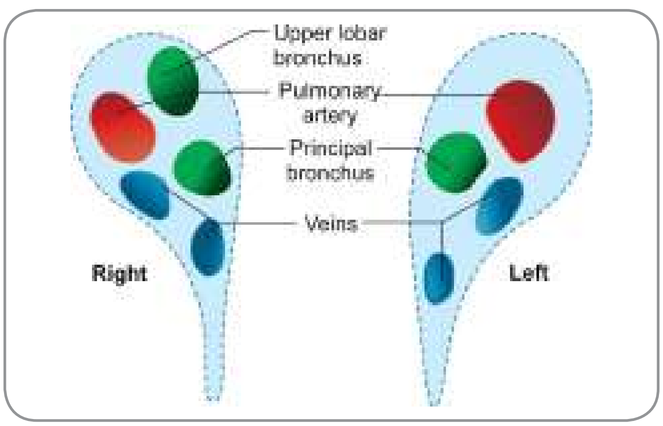


Fig. 6.16: Relationship of bronchi, artery and vein at the hilum of right and left lungs

- The ***left pulmonary artery*** is first anterior to the bronchus and then superior to it.
- The ***upper left pulmonary vein*** also crosses in front of the bronchus (Fig. 6.16).

Histology

Structure of bronchi: Structure of the principal bronchi is as that of trachea. As the principal bronchus divides, changes are seen in microstructure of the intrapulmonary bronchi which are as follows:

- The cartilages in the walls of the bronchi become irregular and become progressively lesser. The cartilage is completely absent in the bronchioles which is the distinguishing feature of the bronchiole.
- The amount of the muscle progressively increases as the bronchi become smaller. It is this muscle component, which when contracts, leads to bronchospasm in asthma (clinical condition presenting as difficulty in breathing).
- Subepithelial lymphoid tissue increases with fewer glands as bronchi become smaller. Glands are absent in the walls of the bronchioles.
- The lining epithelium also undergoes gradual change from ciliated columnar pseudo stratified cells in the main bronchi to simple ciliated columnar, nonciliated columnar in smaller bronchi and finally cuboidal epithelium in the respiratory bronchioles.
- Apart from typical ciliated columnar cells, other cells that are found in the smaller bronchi and bronchioles are numerous goblet cells, nonciliated serous cells, basal cells and Clara cells (which produce a secretion that spreads over the alveolar cells to reduce their surface tension).

VASCULAR LYMPHATICS AND NERVE SUPPLY OF TRACHEA AND BRONCHI

- The trachea receives its blood supply mainly through the inferior thyroid arteries (lying in the neck). The blood is drained through the inferior thyroid veins.
- The bronchi are supplied by bronchial arteries that also supply the lower end of the trachea.

- The trachea and bronchi are innervated by sympathetic and parasympathetic nerves. The sympathetic nerves cause dilatation of bronchi while parasympathetic nerves cause constriction.
- The lymph vessels of the trachea drain into the pretracheal and paratracheal lymph nodes.

LUNGS

The lungs are a pair of essential organs of respiration and lie in the corresponding halves of the thoracic cavity. They are separated from each other by the structures in the mediastinum (including the heart, the great vessels, the trachea, and the oesophagus). They are porous, elastic, spongy structures and crepitate to touch. They are elastic and have the capacity to recoil; if the thoracic cavity is opened, the lungs recoil to a much smaller size. Their main function is to oxygenate blood by bringing the inspired air closer to the blood in the pulmonary capillaries, thus facilitating exchange of gases.

Each lung is half conical in shape and presents an ***apex*** (relatively narrow upper end), ***base*** (broad inferior surface), a rounded ***lateral*** or ***costal surface*** *and* a ***medial surface and three borders.*** The costal surface meets the medial surface, anteriorly, at the ***anterior border*** and behind at the ***posterior border***. The costal and medial surfaces end, below, in an ***inferior border*** by which they are separated from the base. The surface of the lung is free all around and is covered by pleura (visceral layer) except at an area of the medial surface called the ***hilum***. The principal bronchus and the pulmonary artery enter the lung, and the pulmonary veins leave it, at the hilum (Figs 6.16).

The right lung is larger, heavier, shorter and wider than the left; Its anterior border is almost straight. It has two fissures, the right oblique and the horizontal fissures; they divide the lung into three lobes, namely the superior, the middle and the inferior lobes.

The left lung has an anterior border that is deeply indented due to the deviation of the heart to the left. This indentation is the cardiac notch. The notch primarily indents the anteroinferior aspect of the superior lobe and thins out the latter into a tongue like process called the ***lingula*** (latin.lingula= small tongue). The lingula projects below the cardiac notch; it moves into and out of the costomediastinal recess during inspiration and expiration.

EXTERNAL FEATURES

Apex

The apex is the rounded superior end of the lung situated at the root of neck. As the thoracic inlet is obliquely placed, the summit of the apex lies about 2.5 cm above the medial end of the clavicle. It is covered by the cervical pleura and the supra pleural membrane.

Development

Development of lungs and pleura

The respiratory system develops from a median ventral diverticulum of the foregut. In an embryo of 3–4 weeks old, a small groove appears on the internal aspect of the ventral wall of the developing foregut just behind the hypobranchial eminence. This groove is called the ***tracheo-bronchial groove***. The groove deepens and pushes the foregut wall as an evagination. The evagination further elongates and grows into the splanchnic mesoderm present on the ventral surface of the gut tube. It is now called the ***respiratory diverticulum***. Two ridges appear on the inner aspect at the angle between the respiratory diverticulum and the foregut (which, by now, has transformed into an elongated developing oesophagus). The ridges, which are right and left, soon fuse. Fusion proceeds from the lower to the upper level. Because of fusion, the respiratory diverticulum is separated off from the oesophagus except near the hypobranchial eminence where a small communication remains between the two. This communication is the ***primitive laryngeal aditus***.

At about the same time, the caudal end of the respiratory diverticulum (which proceeds to elongate and grow into the splanchnic mesoderm at a rapid pace, especially after its separation from the oesophagus) shows ***dichotomous branching***. Thus the caudal end becomes bilobed. Each division further divides and redivides dichotomously. The two divisions of the first dichotomy become the ***two principal bronchi*** and the mass of further divisions constitute a ***lung bud***. The splanchnic mesoderm around each lung bud condenses to form a serous membrane which now can be termed the ***visceral pleura*** of the corresponding lung. The blind extremities of the lung bud proliferate and develop rapidly and form the bronchial tree and the respiratory epithelium. By the end of fifth week, the primitive lungs show marked growth and lobulation.

The median undivided part of the respiratory diverticulum gives rise to the ***trachea*** (lower part)and the larynx (upper part). The tracheal rings differentiate from the surrounding splanchnic mesoderm. The laryngeal cartilages also develop from the same mesoderm by the 2nd month and the laryngeal muscles by the 5th month.

Though the lungs are almost fully formed by the 6th–7th of intrauterine life, they become functional only at birth. The lung bud goes through three phases of development: a**.** ***glandular phase***, till the 4th month, when the division of bronchial tree occurs; b. ***canalicular phase***, from 4th to 6th month, when the distal divisions of the tree develop respiratory tissue qualities; c. ***alveolar phase***, from 6^{th} month to full term, when vasculature develop and alveolar tissue differentiation takes place. The alveoli develop their full potential only after birth. Once respiration is established at birth, the alveoli, which until then remain collapsed, dilate and acquire their true alveolar form. This postnatal dilatation starts in the central parts of the lungs and the peripheral alveoli are fully expanded only by the 3rd or 4th day of life.

Relations

- ***Anterior:*** Subclavian artery, origin of internal thoracic artery, subclavian vein and scalenus anterior muscle;

- ***Posterior:*** Neck of 1st rib and structures that intervene between the rib and the lung, namely, sympathetic trunk, first posterior intercostal vein, superior intercostal artery and ascending branch of the ventral ramus of the first thoracic nerve from medial to lateral;
- ***Lateral:*** Scalenus medius muscle and lower trunk of brachial plexus;
- ***Medial:*** Differs between the two sides
- ***Right Lung:*** Right brachiocephalic vein, brachiocephalic trunk, trachea, vagus nerve
- ***Left Lung:*** Left Brachiocephalic vein, left subclavian artery, left edge of oesophagus, thoracic duct.

Base

It is the concave inferior surface of the lung, semi lunar in shape and sometimes referred to as the diaphragmatic surface. On both sides, the base is related to the corresponding part of the diaphragm separated by the pleural sac. Below the diaphragm, the base is related to the right lobe of liver on the right side and left lobe of liver, stomach and spleen on the left side. The concavity of this surface is deeper on the right side due to the higher position of the right dome of diaphragm (which in turn is due to the firmness of the liver). Laterally and posteriorly, this surface is bounded by the thin and sharp inferior border that projects into the costodiaphragmatic recess.

Costal Surface (Figs 6.17 and 6.18)

It is the convex external surface that stretches from the anterior to the posterior aspect around the lateral side. It is rounded to conform to the shape of the ribs (and intercostal spaces) and is related to the lateral thoracic wall separated by the costal pleura and endothoracic fascia. The surface is related to the upper six ribs in the mid clavicular line; the upper eight ribs in the mid axillary line and the upper ten ribs in the scapular line.

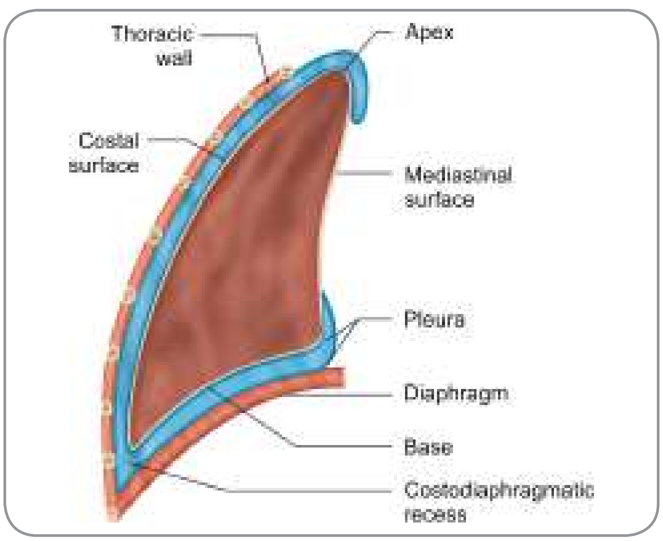


Fig. 6.17: Coronal section through right lung to show its surfaces

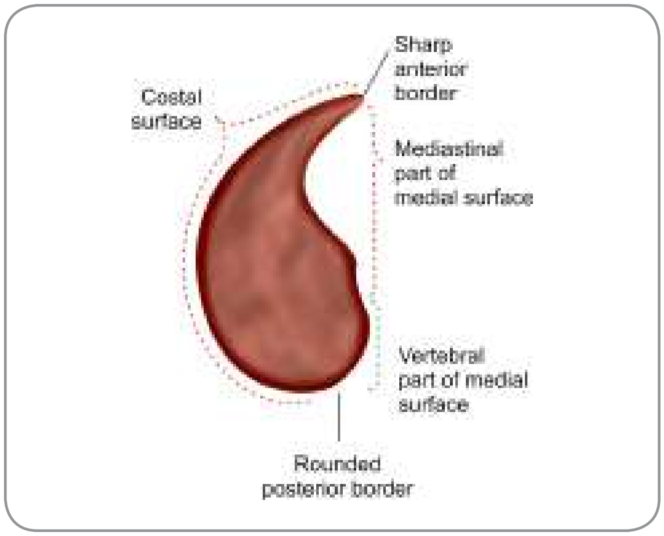


Fig. 6.18: Transverse section through left lung to show its surfaces and border

Medial Surface (Figs 6.17 and 6.18)

It is the surface that faces internally and is further divided into a ***posterior (vertebral) part*** and an ***anterior (mediastinal) part***.

- ***Vertebral part:*** It is flat and related to the bodies of vertebrae and intervertebral discs of upper ten thoracic vertebrae, posterior intercostal vessels and to the greater and lesser splanchnic nerves in the lower portion.
- ***Mediastinal part:*** It is that part of the medial surface that is related to the mediastinum. The main feature of this surface is the hilum. All structures which enter and exit the lung go through the hilum. Though the hilum per se does not have any pleural covering, the reflection of the visceral layer as the parietal layer takes place around the hilum; hence, in a cadaveric isolated specimen of the lung, the cut edge of the pleural reflection can be seen around the hilum.
  However, the disposition of various structures both in the hilum and the rest of the mediastinal surface differs between the right and the left sides.

RIGHT LUNG (TABLE 6.1)

Arrangement of the structures within the hilum are as follows (Fig. 6.19):

- ***From above downwards:*** Upper lobar bronchus, pulmonary artery, right principal bronchus, lower pulmonary vein.
- ***From before backwards:*** Upper Pulmonary vein, pulmonary artery, bronchus with bronchial vessels.

The mediastinal surface of the right lung is also related to the heart. A shallow concave impression for the heart is present in front of the hilum and is related to the ***right atrium***, including its auricle. The anteriormost part of the

Table 6.1: Differences between right and left lungs	
Right lung	**Left lung**
Shorter, wider, more capacious	Longer, narrower, less capacious
Heavier	Lighter
Three lobes separated by two fissures	Two lobes separated by one fissure
Base is more concave	Base is more shallow
Absence of cardiac notch	Presence of cardiac notch
Arrangement of structures at the hilum from above downwards-bronchus, artery, bronchus, vein	Arrangement of structures at the hilum from above downwards-artery, bronchus, vein
Shallow cardiac impression	Deep cardiac impression
Absence of lingula	Presence of lingula
Supplied usually by one bronchial artery	Supplied by two bronchial arteries
Branching pattern and broncho pulmonary segments as detailed below	Branching pattern and broncho pulmonary segments as detailed below

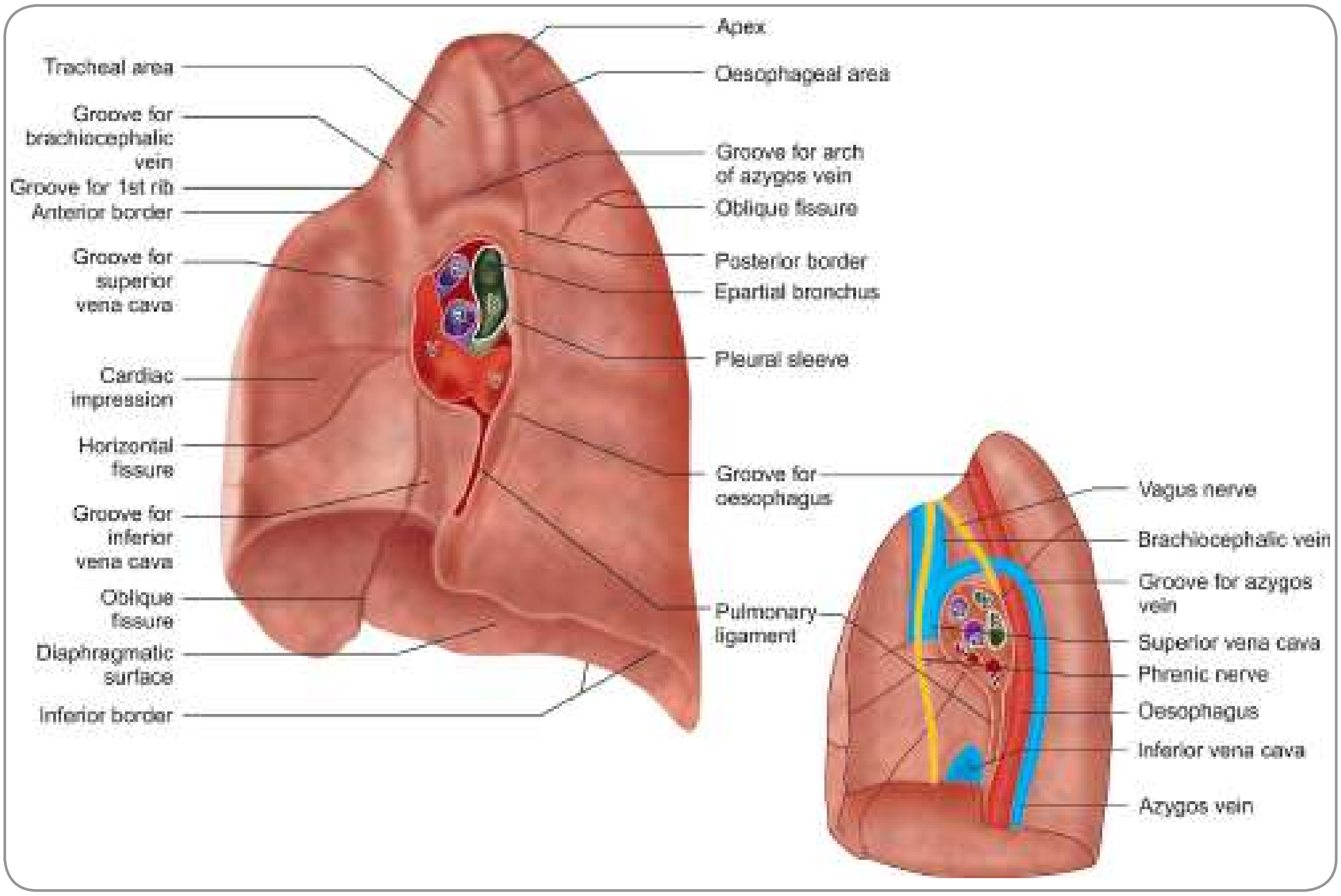


Fig. 6.19: Right lung viewed from the medial side showing areas related to various structures—pulmonary artery and its branches are shown in purple because they contain deoxygenated blood; pulmonary veins marked red because they contain oxygenated blood

Key: a. Artery **b.** Bronchus **v.** Vein

impression is related to the ***right ventricle***. The posterior part of the cardiac impression is continuous below with a short, wide groove. The thoracic part of the ***inferior vena cava*** lies in this groove. In continuity with the upper part of the cardiac impression, a prominent vertical groove is present which lodges the ***superior vena cava*** and the lower end of the ***right brachiocephalic vein***.

A narrow groove arches forward above the hilum and meets the groove for the superior vena cava. This groove is produced by the ***vena azygos*** which drains into the SVC.

Along the posterior margin of the mediastinal area, is a wide shallow groove for the ***oesophagus***. This groove is interrupted near its middle by the groove for the vena azygos. The area of the lung lying between the upper part of the groove for the oesophagus (behind) and the groove for the superior vena cava (in front) is in contact with the right side of the ***trachea***.

A little below the apex, the anterior aspect of the lung is marked by a notch for the ***subclavian artery***.

Apart from these major structures, smaller structures in the mediastinum that come into contact with the right lung are the ***right vagus***, which lies between the trachea and the lung, the ***right phrenic nerve*** which comes in contact (from above downwards) with the groove for the right brachiocephalic vein, the groove for the superior vena cava, the part of the cardiac impression related to the right atrium and the groove for the inferior vena cava.

LEFT LUNG

Arrangement of the structures within the hilum are as follows (Fig. 6.20):

- ***From above downwards:*** Pulmonary artery, left principal bronchus, lower pulmonary vein.
- ***From before backwards:*** Upper Pulmonary vein, pulmonary artery, bronchus with bronchial vessels.

The other important structure related to the left lung is the heart. The cardiac impression is deeper compared to the right lung and is related mainly to the ***left ventricle***. The anterior part of the impression overlies the ***right ventricle***, including the ***infundibulum***.

Another conspicuous feature is seen as a wide groove that forms an arch above and behind the hilum, and extends below right up to the lower end of the medial surface. This groove is related to the ***aorta***. The upper part is for the ***arch of the aorta***, and the lower part for the ***descending thoracic aorta***. Continuous with the upper margin of the groove for the arch of the aorta there are two smaller, vertical grooves. The posterior of these lodges the ***left subclavian artery***, and the anterior one lodges the ***left common carotid artery***. As the subclavian artery passes laterally across the anterior aspect of the lung it produces a notch a little below the apex.

The ***oesophagus*** comes into relationship with the upper part of the left lung behind the groove for the subclavian artery. It may also be related to the lower part of the medial surface in front of the groove for the aorta.

The other smaller structures that are related to the mediastinal surface of the left lung are the ***left phrenic*** and ***vagus nerves***, both of which lie against the lung in the interval between the left subclavian and left common carotid arteries and pass over the groove for the arch of the aorta, the phrenic nerve that continues downwards over the cardiac impression, the ***thoracic duct*** that runs vertically between the lung and the upper part of the oesophagus and the ***left superior intercostal vein*** which is related to the groove for the arch of the aorta.

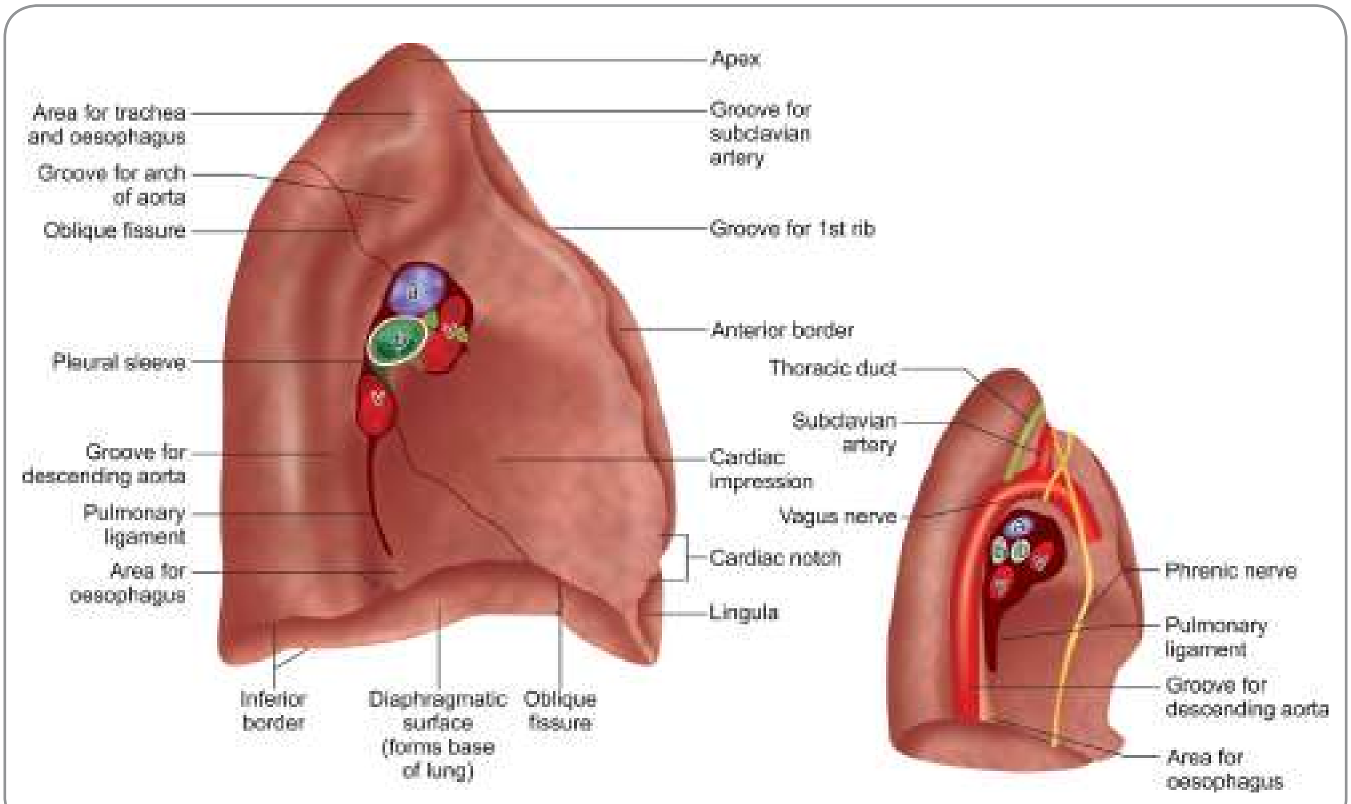


Fig. 6.20: Left lung viewed from the medial side showing areas related to different structures

Key: a. Artery **b.** Bronchus **v.** Vein

Anterior Border

The ***anterior border*** is thin and is present between the anterior thoracic wall and pericardium. The anterior border of both the lungs follow the costomediastinal reflection. However, at the level of 4th costal cartilage, the anterior border of the left lung deviates for the accommodation of the heart which is seen as the ***cardiac notch*** (Fig. 6.18).

Posterior Border

It is thick and rounded as it occupies the paravertebral gutter. It is related to the heads of the upper ten ribs, sympathetic trunks and splanchnic nerves (Fig. 6.18).

Inferior Border

It is a circumscribed border which separates the base of the lung from the costal and medial surfaces (Fig. 6.18).

FISSURES AND LOBES (FIG. 6.20)

A prominent ***oblique fissure*** is present in both the right and left lungs. The fissure begins at the posterior border of the lung (about 6 cm below the apex) and runs downwards and forwards through the lung substance, to emerge on the anterior most part of the base. It passes through the inferior border of the lung at the 6th costochondral junction and finally reaches the lower and anterior part of the hilum. An additional ***horizontal fissure*** is present in the right lung. This fissure starts at the anterior border (a little below its middle) at the level of the 4th costal cartilage and passes backwards through the lung substance to meet the oblique fissure (Fig. 6.19).

The part of the left lung above and in front of the oblique fissure is called the ***upper lobe***. The part below and behind the oblique fissure is called the ***lower lobe***. In the right lung, because of the presence of the additional horizontal fissure, the part of the right lung in front of and above the oblique fissure is subdivided into a part above the horizontal fissure called the ***upper lobe*** and a part below the fissure called the ***middle lobe***. The lower lobe corresponds to that of the left lung. Sometimes ,the medial part of the upper lobe of right lung is partially separated by a fissure of variable depth containing the terminal part of azygos vein, enclosed by a projection of mediastinal pleura. This lobe is called the ***lobe of azygos vein***.

The anterior margin of the left lung has a deep cardiac notch. Because of the presence of this notch the lowest part of the superior lobe of this lung has the appearance of a tongue-like projection. This projection is called the ***lingula***.

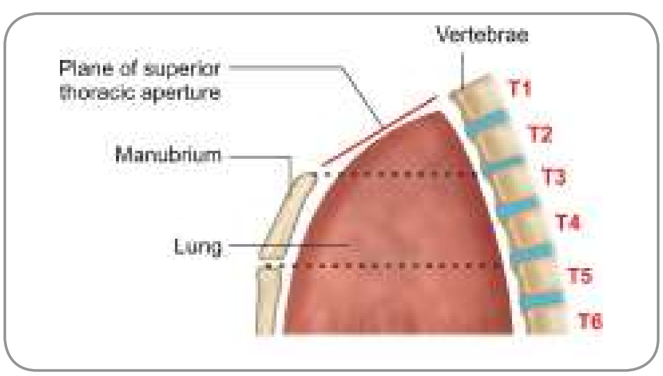


Fig. 6.21: Scheme to show why the apical part of the lung is seen in the front of the neck

ROOTS

As already noted, the lungs are attached to the mediastinum by their 'roots'. The roots comprise the bronchi and their associated bronchial vessels, the pulmonary arteries, the superior and inferior pulmonary veins, the pulmonary plexuses of nerves including the sympathetic, parasympathetic and visceral afferent fibres and the lymphatic vessels. If the root is sectioned close to the mediastinum and the lung removed to see the hilar structures, a general arrangement can be seen. This general arrangement is as follows:

- ***Pulmonary artery:*** It is the superiormost on the left side; the superior lobar bronchus is superiormost on the right side and hence is called 'eparterial' (Ep=above);
- ***Superior and inferior pulmonary veins:*** The anteriormost and the inferiormost respectively;
- ***Main bronchus:*** Approximately in the middle of the posterior boundary of the hilum with the bronchial vessels on its posterior aspect.

The root of each lung is enclosed in a pleural sleeve, called the mesopneumonium; this sleeve is formed by the reflection of the visceral pleura onto the parietal pleura.

Inferior to the root of the lung, the pleural sleeve hangs loose for some distance and extends between the lung and the mediastinum. This portion that hangs down is called the ***pulmonary ligament***. The pulmonary ligament thus consists of a double layer of pleura with a little amount of connective tissue between. The ligament provides potential space for expansion when the pulmonary veins engorge with blood.

STRUCTURE

Histology

The lung is composed from outside inwards of serous coat, subserous areolar tissue and pulmonary substance.
The serous coat is derived from the visceral/pulmonary pleura and intimately invests the entire lung except the hilum and pulmonary ligament.

contd...

Histology

The sub-serous coat is made up of elastic, fibrous tissue which projects into the substance of the lung as fibro-elastic septa and divide the lobes of the lung into lobules.The primary lobule is the lung distal to the respiratory bronchiole. The secondary lobule is the smallest subsection of the peripheral lung, comprising of approximately six terminal bronchioles separated by septa.

The epithelial lining of the air passages is supported by a basal lamina and lamina propria. Numerous elastic fibres are present within the basal lamina and lamina propria which ultimately become continuous with the elastic fibres present in the walls of the air sacs. The elastic fibres are responsible for providing the physical basis for the elastic recoil of the lung tissue.

Rest of the lung is composed of the intrapulmonary bronchi, smaller bronchi, bronchioles which have been described earlier. The terminal portion of the respiratory bronchioles end in the alveoli which are responsible for the primary function of the lung namely ***gaseous exchange***.

Each respiratory bronchiole ends by dividing into ***alveolar ducts***. Each alveolar duct ends in a passage, the ***atrium***, which leads to number of rounded ***alveolar sacs***. Each alveolar sac is studded with a number of ***air sacs or alveoli (Fig 6.24).***

The alveoli are blind sacs having very thin walls through which oxygen passes from air to blood and carbon dioxide passes from blood to air. The alveolar wall is lined by flattened squamous epithelial cells called as ***pneumocytes***, which rest on a basement membrane. Deep to the basement membrane, a layer of delicate connective tissue is present in which pulmonary capillaries run. The capillaries are lined by endothelial cells resting on a basement membrane. Hence, the barrier between air and blood (***air-blood barrier***) is made up of the ***alveolar epithelial cells*** and their ***basement membrane***, ***capillary endothelial cells*** and their ***basement membrane*** with intervening connective tissue.

The pneumocytes are of two types—***Type I alveolar epithelial cells*** are numerous in number, form 90% of the lining, and are united by tight junctions to prevent leakage of blood from capillaries to alveolar lumen.

Scattered in the epithelial lining are the second type of alveolar epithelial cells which are rounded secretory cells bearing microvilli. They are the ***Type II alveolar epithelial cells***. These cells are less in number and secrete a fluid which forms a film over the alveolar epithelium. The secretion is called as ***pulmonary surfactant*** which reduces the surface tension and prevents collapse of the alveoli during expiration.

The area of the lung supplied by ***one terminal respiratory bronchiole*** is known as the ***pulmonary/lung unit***.The unit includes one terminal respiratory bronchiole, 3 successive orders of dichotomous alveolar ducts, atria, air saccules and alveoli.

Dissection

The lungs can better be studied in samples of specimens. However, make a thorough study of the thoracic cavity and its contents in prosected or museum specimens. Review with your theory knowledge, the position of the pleural cavities, the position of the lungs, the mediastinum and its location and the various structures located in all these areas.

contd…

Dissection *contd…*

Hold specimens of lungs in hand. Feel for the spongy texture of the organ. Closely observe the freckled spots on its surface and the colour that it exhibits. In a newborn, the lungs are light pink in colour. Compare the colour of the specimen that you hold with this information; life-long breathing in and out of various kinds of air-borne chemicals, smoke and pollutants are responsible for the change in colour.

The trachea should be studied in prosected specimens of the thoracic cavity and the neck. Utilise available opportunities to study the bronchial tree in radiographic pictures.

Bronchopulmonary Segments of the Lungs

The bronchopulmonary segments are well defined, wedge shaped sectors of the lung, aerated by segmental/tertiary bronchi (Table 6.2). Each segment is an independent respiratory unit by itself and is supplied independently by a single segmental bronchus. It is the largest subdivision of a lobe. The base of the wedge is directed to the surface of the lung and is separated from the adjacent segments by intersegmental alveolar septa occupied by the intersegmental tributaries of the pulmonary veins (Fig. 6.22). The intersegmental veins drain adjacent parts of the adjacent segments. Each bronchopulmonary segment is also supplied by a tertiary branch of the pulmonary artery.

Bronchopulmonary Segments of Right Lung (Figs 6.23A and B)

As seen earlier, the right principal bronchus gives off the ***superior lobar bronchus*** (the eparterial secondary bronchus) just before entering into the hilum of the right lung (Table 6.2). The bronchus enters into the hilum, descends for a short distance and divides into two lobar bronchi: one for the middle lobe and one for the inferior lobe.

- The ***superior lobar bronchus*** divides into three segmental bronchi—(1) apical, (2) posterior and (3) anterior.
- The ***middle lobar bronchus*** divides into two segmental bronchi—(1) lateral and (2) medial.
- The ***inferior lobar bronchus*** gives off five segmental bronchi—(1) Superior, (2) Medial basal, (3) Anterior basal, (4) Lateral basal and (5) Posterior basal.

Thus, there are a total of ten bronchopulmonary segments in the right lung.

Bronchopulmonary Segments of Left Lung (Figs 6.23C and D)

The left principal bronchus enters into the left lung and divides into two lobar bronchi: ***superior*** and ***inferior*** (Table 6.2).

- The superior lobar bronchus divides into two main branches—cranial and caudal.

Table 6.2: Bronchopulmonary segments

Right lung		**Left lung**	
Lobe	***Segments***	***Lobe***	***Segments***
Superior	Apical, Posterior, Anterior	Superior	Apical, Posterior, Anterior
Middle	Lateral, Medial		Superior lingular, Inferior lingular
Inferior	Superior, Medial basal, Anterior basal, Lateral basal, Posterior basal	Inferior	Superior, Medial basal, Anterior basal, Lateral basal, Posterior basal

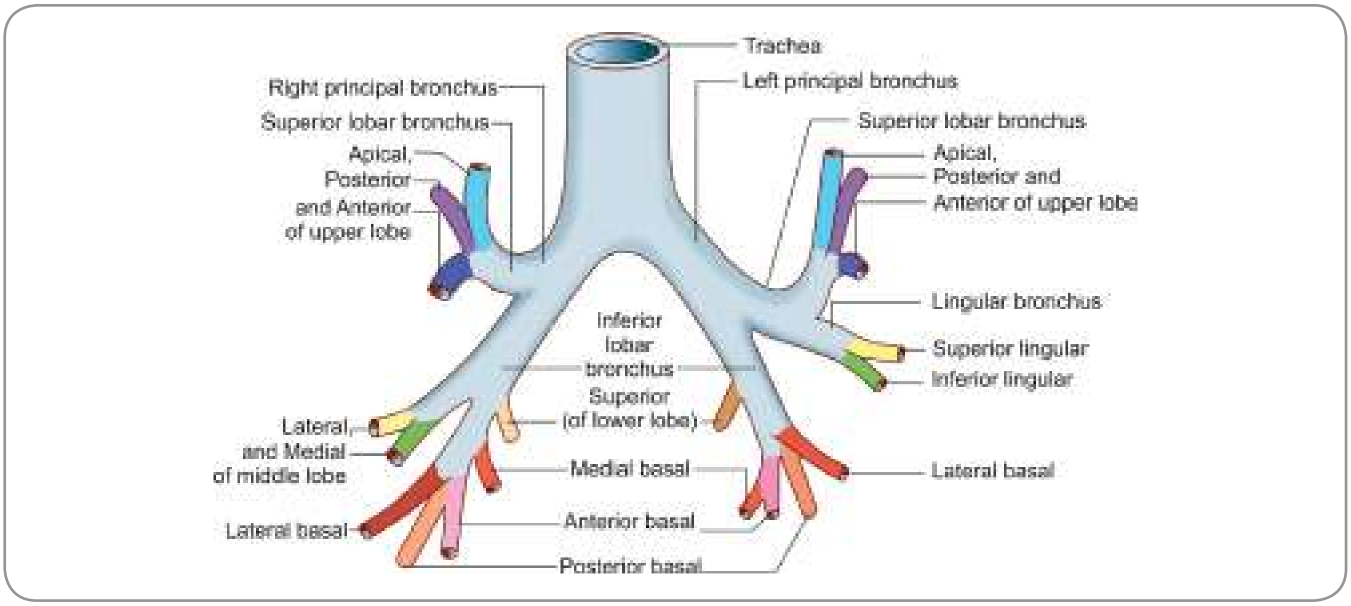
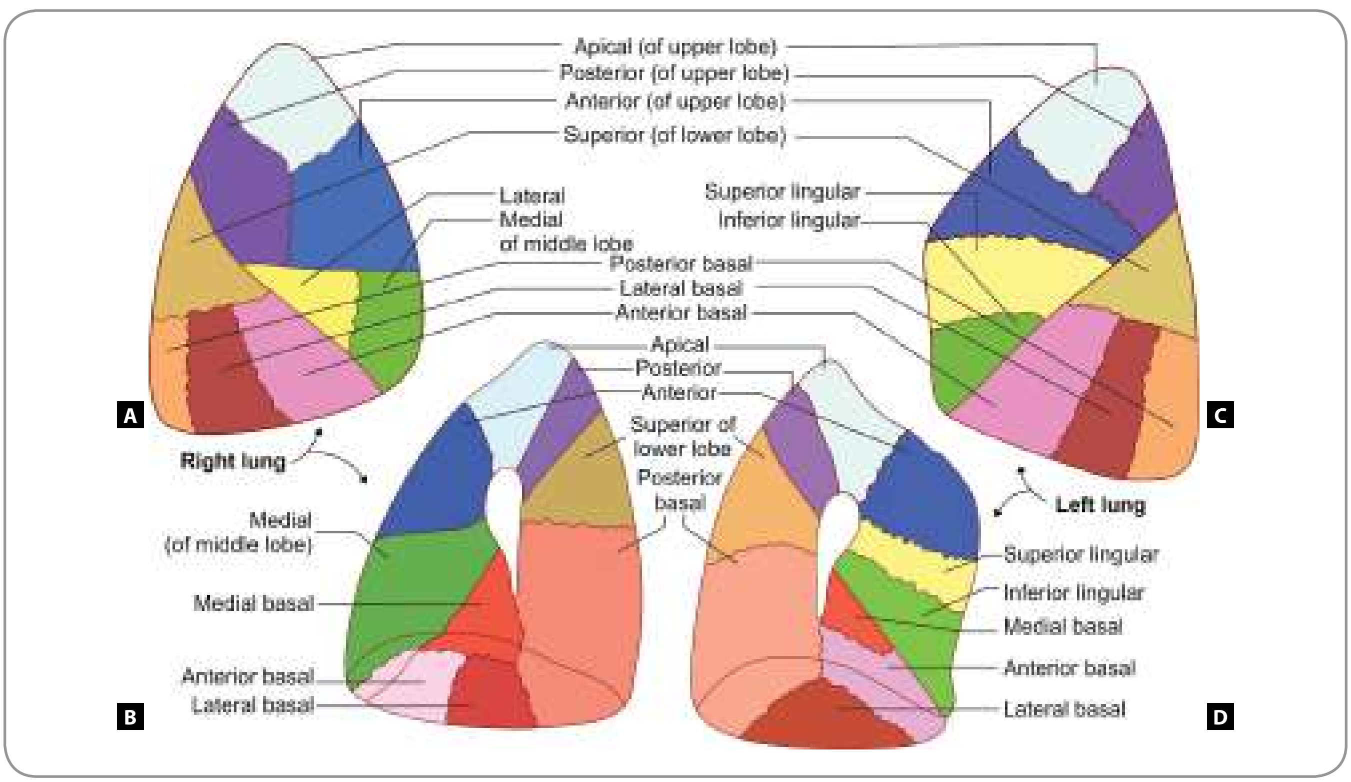


Fig. 6.22: Scheme to show the bronchial tree as seen from the front



Figs 6.23A to D: Bronchopulmonary segments of the right and left lungs

- The ***cranial branch*** is the equivalent of the superior lobar bronchus of the right lung. It divides into apical, posterior and anterior segmental bronchi.
- The caudal branch of the superior lobar bronchus is also called the ***lingular bronchus***. It is the equivalent of the middle lobar bronchus of the right lung. It divides into superior and inferior lingular bronchi. It is important to note that the segments of the middle lobe of the right lung are designated as medial and lateral. The corresponding segments in the left lung are designated superior and inferior.
- The inferior lobar bronchus gives off superior, medial basal, anterior basal, lateral basal, and posterior basal segmental branches as in the right lung.

Thus, the left lung also has ten bronchopulmonary segments (Table 6.2).

However, the following ***differences in the segmental bronchi of the right and left lungs*** are worthy of note.

- In the upper lobe of the left lung the apical and posterior segmental bronchi arise by a common stem. Some authorities, therefore, speak of an ***apicoposterior*** bronchopulmonary segment (combining the apical and posterior segments).
- In the lower lobe of the left lung, the medial basal bronchus is relatively small and appears as a branch of the anterior basal branch. Some authorities, therefore, consider the part supplied by the medial basal bronchus to be a part of the anterior basal segment.

Hence, some authorities, especially respiratory physicians recognise only eight bronchopulmonary segments in the left lung.

BLOOD VESSELS

Arterial Supply

The blood supply of the lungs is peculiar in that two sets of arteries carry blood to them. The pulmonary arteries convey deoxygenated blood from the right ventricle. This blood circulates through a capillary plexus intimately related to the walls of the alveoli, and receives oxygen from the alveolar air. This blood, which is now oxygenated, is returned to the heart (left atrium) through the pulmonary veins.

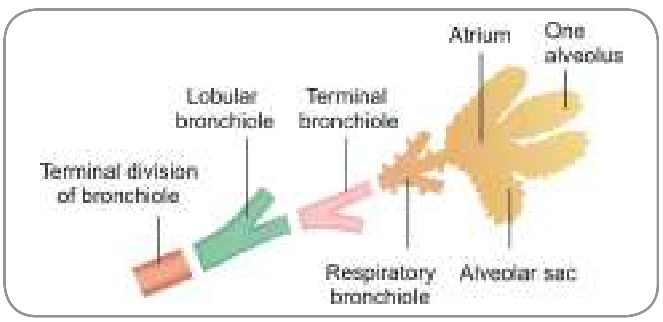


Fig. 6.24: Scheme to show the terms used to describe the terminal ramifications of the bronchial tree

The lungs also receive oxygenated blood like any other tissue in the body. This is conveyed to them through the bronchial arteries. The right lung is supplied by one bronchial artery whereas the left lung by two bronchial arteries. The bronchial arteries arise from the descending thoracic aorta. Sometimes the right bronchial artery arises from the third right posterior intercostal artery. The bronchial artery enters through the hilum of the lung, supplies the walls of the bronchi till the respiratory bronchioles, walls of the pulmonary vessels, the connective tissue of the lung and the hilar lymph nodes. The capillaries of the bronchial arteries anastomose with the capillaries of the pulmonary arteries in the walls of the terminal bronchioles and in the visceral pleura; this anastomosis forms the pulmonary capillary plexus.

Within each lung the pulmonary artery divides into branches that follow the branching pattern of the bronchi. Each bronchopulmonary segment thus has its own artery. As a rule, the arteries lie posterolateral to the corresponding bronchi.

Hence, nutrition to the lungs is derived from two sources the conducting part till the level of the respiratory bronchioles is supplied by the bronchial arteries; the respiratory part is actually supplied by the pulmonary arteries via the pulmonary capillary plexus.

Venous Drainage

As similar to the arterial supply, the venous drainage is also by two ways. One is by the ***bronchial veins*** and the other by the ***pulmonary veins.*** However, the corresponding venous drainages are not coextensive to their arterial territories.

The bronchial venous drainage is by two sets of venules: ***Superficial and Deep***. The ***superficial set drains*** blood from pulmonary pleura near the lung root, extrapulmonary bronchi (proximal portions of bronchi) and hilar lymph nodes; it finally drains into the arch of azygos vein in the right side and left superior intercostal vein (or sometimes the accessory hemi azygos vein) in the left side. The ***deep set drains*** the bronchioles, the intrapulmonary bronchi (peripheral and distal regions of lung) and the visceral pleura; it terminates into one of the pulmonary veins.

On each side, the lung is drained by two pulmonary veins, namely, the superior and the inferior. The middle lobar vein drains into the superior pulmonary vein. The pulmonary veins run in the intersegmental space and drain the adjacent segments. Running to the hilum, the veins reach the mediastinum and the heart to enter the left atrium.

As the deep set of bronchial venules drain into the pulmonary veins, some amount of low-oxygen blood mixes with large volumes of oxygen rich blood.

LYMPHATIC DRAINAGE

Two sets of lymphatic plexuses drain the lungs and pleurae. Both the plexuses communicate freely.

The superficial plexus lies deep to the visceral pleura and thus drains the lung parenchyma and the visceral pleura. It is called the subpleural lymphatic plexus; the lymphatic vessels which start from this plexus drain into the bronchopulmonary nodes at the hilum.

The deep plexus lies in the submucosa of the bronchi and in the peribronchial connective tissue. It drains the structures which form the root of the lung. The lymphatic vessels which arise from this plexus drain first into the pulmonary lymph nodes which are located along the lobar bronchi. The efferents from the pulmonary nodes follow the bronchi, reach the hilum and drain into the bronchopulmonary lymph nodes.

Efferents from the bronchopulmonary nodes reach the superior and inferior tracheobronchial lymph nodes which lie superior and inferior to the bifurcation of the trachea. Lymph from the tracheobronchial nodes go through the right and left bronchomediastinal lymph trunks which join the venous stream either directly or through the right lymphatic and thoracic ducts. Lymph vessels are conspicuously absent around the alveolar walls as the air may be sucked into the lymph vessels and thence into the blood.

NERVE SUPPLY

Lungs are supplied by anterior and posterior pulmonary plexuses. The plexuses are formed by both parasympathetic and sympathetic nerves. The parasympathetic nerve fibres are from the vagus nerve and sympathetic fibres are from upper 4 or 5 thoracic sympathetic ganglia of the sympathetic trunks. Parasympathetic motor fibres are motor to the smooth muscles of the bronchi (bronchoconstrictor), secretomotor to the bronchial glands and inhibitory to the pulmonary vessels(vasodilator). Sympathetic motor fibres are broncho dilators, vasoconstrictor and inhibitory to the glands.

Visceral Sensory fibres from the lungs travel along with the parasympathetic fibres. Around the lung alveoli, they act as stretch receptors and are concerned with reflex control of respiration. They are associated with tactile sensations for cough reflex, are sensitive to blood pressure and to blood gas levels.

Added Information

- The parietal pleura is supplied by the intercostal arteries and drained by veins in the thoracic wall.
- The lymphatics from the parietal pleura drain into the lymph nodes of the thoracic wall, namely, the intercostals, parasternal, mediastinal and phrenic nodes. Lymph from cervical pleura may reach the axillary nodes.

Clinical Correlation

Investigations of the Respiratory System

Clinical Examination

- ***Percussion and Auscultation*** of the thorax gives a great deal of information about lung diseases, and is an essential part of the physical examination of a patient suspected to have a respiratory problem.
- A clinician examining the chest needs to know the relationship of lobes of the lungs to the thoracic wall for which the surface projections need to be known.

Plain Skiagram

A plain skiagram (X ray picture) of the chest (Postero- Anterior or PA view) is the most common investigation for detecting structural abnormalities within the chest. It provides useful information about the bones of the thorax, the lung fields, the heart, the diaphragm and the mediastinum. In some cases it can establish diagnosis (e.g., in pleural effusion), and in many others it may give clues that aid further investigation. Right and left oblique views are also sometimes used.

Fluoroscopy or Screening

In this procedure, instead of recording the image on film, X-ray images are seen on a fluorescent screen. Although, less detail is seen than in an X-ray film, the technique allows a dynamic study. For example, movements of the domes of the diaphragm associated with inspiration can be visualised.

Computed Tomography and Magnetic Resonance Imaging

These are newer techniques which provide images of the chest with great detail. Sectional views can be obtained. They often help to establish diagnosis in many cases in which routine X-ray examination is inconclusive.

Bronchoscopy and Bronchography

- The interior of the trachea and bronchi can be visualised through an instrument called the ***bronchoscope***. Earlier bronchoscopes were rigid and could be passed only into larger bronchi. More recent bronchoscopes, based on fibre optics, are flexible and can be passed into smaller bronchi.
- Apart from examining the interior of the bronchial tree, bronchoscopy can also be used to obtain bronchial secretions and tissue for examination or to remove foreign bodies that may enter the bronchi.
- At the bifurcation of the trachea, the openings of the principal bronchi are seen, which are separated by a ridge called the ***carina***. The appearance of the carina alters in carcinoma and can thus help in diagnosis.
- ***Bronchography*** is a procedure in which X-ray pictures of the bronchi can be obtained after instilling a radio-opaque substance into them.

Diseases of the Lungs and Bronchi

- Foreign body aspiration can occur into the trachea and bronchi. It is more likely to enter the right bronchus than the left as the right bronchus is wider, shorter and more vertical. A foreign body can become the cause of serious infection.
- Inflammation of bronchi is called ***bronchitis***. It may be acute or chronic. In some cases there is localised or more widespread dilatation of bronchi. These dilatations can become seats of infection. This condition is called ***bronchiectasis***.

contd…

Clinical Correlation *contd…*

- Inflammation in the lung is referred to as ***pneumonia*** or ***pneumonitis***. Inflammations of the lungs and bronchi can be caused by bacteria, by viruses, by allergy, or by irritant action of pollutants in the atmosphere.
- In some cases, serious lung infections cause localised necrosis of tissue leading to formation of a ***lung abscess.***
- Most lung abscesses are caused by inhalation of infective material from infected sinuses (sinusitis), tonsillitis, or dental infection. The apical segment of the lower lobe and the posterior segment of the upper lobe are common sites of lung abcess by aspiration, as these segments are most dependent in recumbent position.
- ***Cavities*** can be formed within the lungs.
- Amongst bacterial infections of the lungs, ***pulmonary tuberculosis*** is an important chronic infection, which when untreated can lead to cavities and abcess formation.The most common site to be affected by tuberculosis is the posterior segment of the right upper lobe leading to decreased air entry in the upper lobe.
- Sensitivity to substances of plant, animal or chemical origin in the atmosphere can also be responsible for diseases that have a predominantly allergic basis.
  - One such condition is ***bronchial asthma*** in which spasm of bronchial muscle causes considerable difficulty in breathing. The difficulty is more pronounced during expiration.
  - Some degree of bronchospasm may also be present in various other conditions seen in the lungs.
- In some cases chronic respiratory obstruction leads to considerable dilatation of alveoli. Large spaces may be formed in the lung parenchyma. This condition is called ***emphysema***. This condition may lead to a ***barrel-shaped chest***.
- Obstruction to a bronchus from any cause can lead to collapse of the part of lung supplied by it. Collapse of part of a lung is referred to as ***atelectasis***. Partial or complete collapse of a lung can also follow pneumothorax or large accumulations of fluid in the pleural cavity,
- Neoplasms of various kinds may be seen in the lungs. The most common of these is ***bronchogenic carcinoma***. The anterior segment of the upper lobe is the most common site for carcinoma.
- As a result of various kinds of inflammatory and degenerative disorders the lungs can gradually undergo fibrosis. Pulmonary fibrosis can greatly reduce the efficiency of the lungs. Loss of elastic tissue makes the lungs much less elastic. This is one reason for decreased respiratory efficiency in elderly persons, other reasons being decreased elasticity of the thoracic cage, and reduced strength of respiratory muscles.
- Difficulty in breathing is referred to as ***dyspnoea***. This can be a feature of any serious lung disease. Dyspnoea can also be produced by obstruction to respiratory passages; and by disturbances of the pulmonary circulation especially when they lead to pulmonary oedema which is briefly considered below.
- In some cases, excessive accumulation of secretions in bronchi may cause respiratory embarrassment and can lead to infection. Drainage of such fluid can be facilitated by placing the patient in a posture that favours flow of such secretions by gravity (***postural drainage***). A good knowledge of bronchopulmonary segments and of the direction of each bronchus is necessary for effective use of the method.

Pulmonary Oedema

Pulmonary oedema is a condition in which serous fluid seeps into lung tissue. It first invades interstitial tissue and later reaches the alveoli. It leads to great difficulty in breathing and lack of adequate oxygenation will lead to cyanosis.

Pulmonary Embolism

Clot forming in any vein may break loose and travel through the bloodstream into the right side of the heart and from there into pulmonary arteries. Depending upon its size, the clot may get lodged in one of the ramifications of a pulmonary artery leading to pulmonary embolism. The effects of pulmonary embolism depend on the size of the vessel blocked. A very small embolism may go unnoticed, while a very large one could result in almost immediate death of the patient. The clot most often originates in the veins of the lower limb or pelvis.

Lung Resection

An entire lung or part of it can be removed by operation. When disease is restricted to one bronchopulmonary segment it is possible to remove the segment without affecting the rest of the lung. This is referred to as ***segmental resection***. In diseases that are more widespread, an entire lobe may be removed (***lobectomy***), or even an entire lung (***pneumonectomy***).

Congenital Anomalies of Lungs and Bronchi

- Part of a lung, or even an entire lung may be absent.
- Various abnormalities in formation of lobes and fissures of the lungs may be seen. ***Accessory lobes*** may be present. They may be directly connected to the trachea, or to the oesophagus, or may have no connection.A part of the upper lobe of the right lung may lie medial to the azygos vein. This part is called the ***azygos lobe***. It is separated from the rest of the lung by a fold of pleura called the ***mesoazygos*** that contains the azygos vein at its lower end. The condition is of special interest as it can be recognised in a plain skiagram. The mezoazygos is seen as a thin line, at the lower end of which the azygos vein casts a circular shadow.
- ***Sequestration of lung tissue:*** An area of lung may not have any communication with the bronchial passages which is called as sequestration of lung tissue. Sequestration is most frequently seen in the lower lobe of the left lung.Such tissue may form a complete lobe (***lobar sequestration***) or a mass within a lobe (***intralobar sequestration***).
- ***Part of a lung may herniate:***
  - Through the inlet of the thorax;
  - Through a defect in the thoracic wall;
  - Into the mediastinum;
  - Into the opposite pleural cavity.

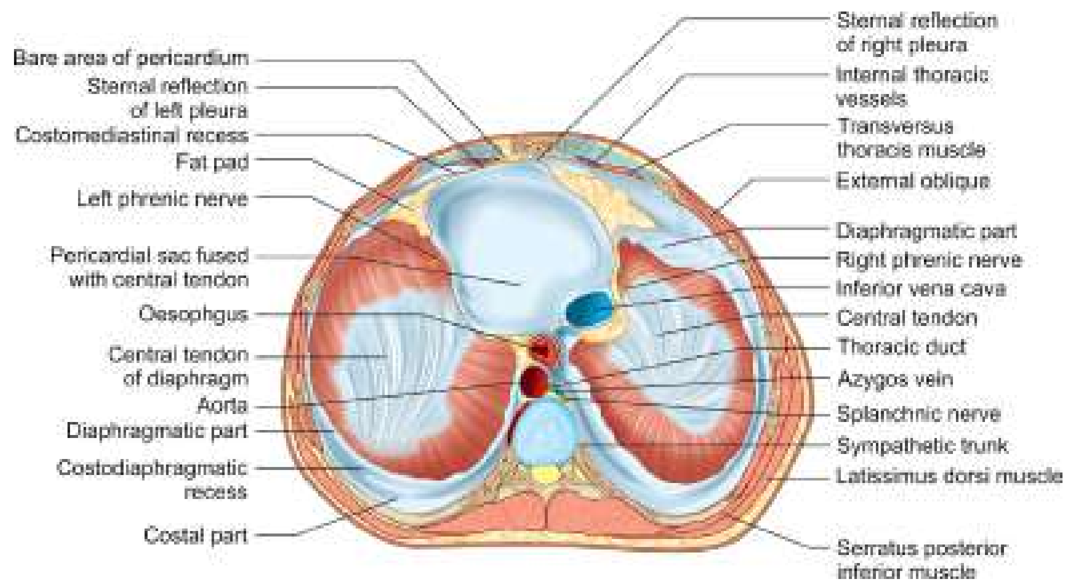


Fig. 6.25: Diaphragm and bases of pleural cavities as seen from above after removing the superior structures

Surface Projection of the Lung

- In visualising the surface projection of the lung, it may be remembered that as the lungs are surrounded by pleura, the limits of the lung must always lie within the boundaries of the pleura, already defined. In some situations, the boundaries are the same as that for the pleura, but in other situations the lungs fall short of the pleura.This is most evident near the costodiaphragmatic reflection of the pleura, where the costal and diaphragmatic pleura are separated by a potential space called the ***costodiaphragmatic recess***. A similar space called the ***costomediastinal recess*** (Fig. 6.25) is present in relation to the anterior border of the left lung.
- It should also be remembered that the limits of the lung described below represent the position in quiet respiration. In deep inspiration, the lungs extend much deeper into the costodiaphragmatic and costomediastinal recesses.
- The outline of the apex of the lung corresponds to that of the cervical pleura.
- The anterior border of the right lung corresponds to the costomediastinal reflection of the pleura described above (Fig. 6.25).
- The anterior border of the left lung up to the fourth costal cartilage follows the pleura, but below this level, the border falls considerably short of the pleura because of the presence of the deep cardiac notch. From the midline (at the level of the fourth costal cartilage) the border passes sharply to the left and downwards so that at the level of the fifth costal cartilage it is about

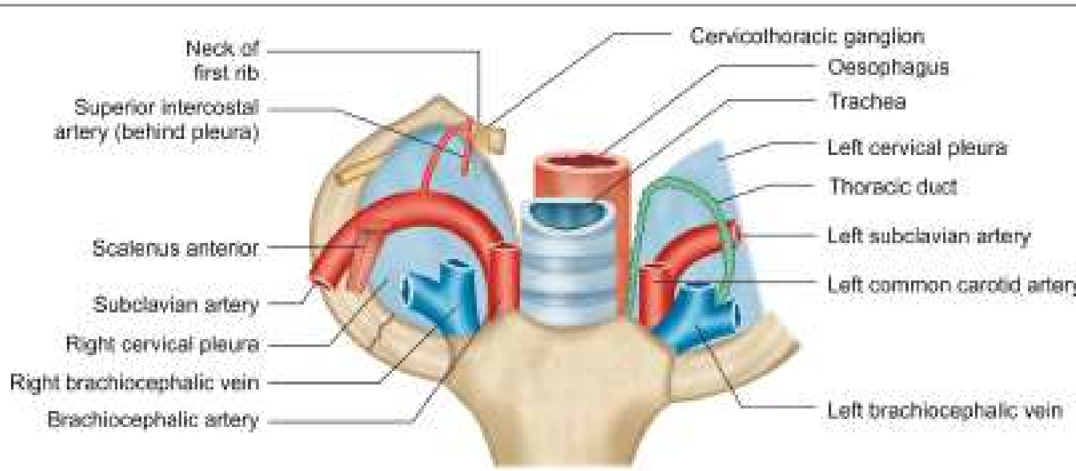


Fig. 6.26: Structures in the root of the neck related to the cervical pleura

3.5 cm lateral to the sternal margin (or to the line for the pleura). It then curves downwards and medially to reach the sixth costal cartilage a short distance lateral to the line for the pleura (i.e., about 4 cm from the midline).

- The projection is similar on the right and left sides
- The inferior border of the lung follows a curved line lying above that for the costodiaphragmatic reflection of the pleura. On each side, the line representing the lower border begins anteriorly at the lower end of the anterior border. In the midaxillary line, it lies over the eighth rib. Its posterior end lies at the level of the tenth thoracic spine 2 cm lateral to the midline.
  - Note that there is a difference of two ribs in the levels of the lung and pleura over both these lines.
- The posterior border of the lung lies 2 cm from the midline. It extends below to the level of the tenth thoracic spine and above to the level of the second thoracic spine.

When seen from behind, the apex of the lung lies at level of the first spine about 5 cm from the midline.

- ***Oblique fissure of lungs mark the following:***
  a. A point 2 cm lateral to the second thoracic spine
  b. A point 3cm lateral to and at the level of nipple
  c. A point on the sixth costal cartilage 7.5 cm from the median plane.

  The upper part of the line joining the points a and b crosses the scapula and is almost parallel to the posterior border of deltoid muscle. The continuation the line joining the points b and c carries the oblique fissure downwards and medially.
- ***Transverse fissure of right lung (Fig. 6.26):***
  a. A point in the median plane at the level of fourth costal cartilage is marked.
  b. A transverse line is drawn above point along the right fourth costal cartilage upto the right mid axillary line, where it meets the oblique fissure.

Multiple Choice Questions

1. Ligamentum arteriosum passes from the inferior surface of the arch of aorta to
   a. Root of left pulmonary artery
   b. Root of right pulmonary artery
   c. Main trunk of pulmonary artery
   d. Left subclavian artery

2. The smallest division of the mediastinum is the
   a. Superior mediastinum
   b. Anterior mediastinum
   c. Middle mediastinum
   d. Posterior mediastinum

3. In an infant of less than one year of age, the tracheal diameter is
   a. More than 4 mm
   b. More than 6 mm
   c. Less than 4 mm
   d. Variable

4. The lingula of the left lung moves into the costomediastinal recess
   a. During inspiration only
   b. During expiration only
   c. During forced inspiration and forced expiration
   d. During inspiration and expiration

5. The lobe of azygos vein is related to a projection of
   a. Mediastinal pleura
   b. Costodiaphragmatic pleura
   c. Costovertebral pleura
   d. Visceral pleura

ANSWERS

1. a **2.** b **3.** c **4.** d **5.** a

Clinical Problem-solving

Case Study 1: A 58-year-old man complained of pain in the neck. He had symptoms of respiratory infection on and off. On examination, he was found to have a friction rub.

- What is the probable diagnosis in this case?
- Why did the patient have neck pain when the basic pathology is elsewhere?
- What is friction rub and what is its anatomical basis?

Case Study 2: A 48-year-old has a pronounced barrel shaped chest. He has been having a history of repeated episodes of respiratory infection.

- Does the incidence of the barrel shaped chest suggest any diagnosis?
- What is the basic cause in such a condition and what anatomical changes happen?
- What is the disease condition called?

(For solutions see Appendix).

Chapter 7

Heart and Pericardium

Frequently Asked Questions

- Discuss the right atrium in detail. Add a note on its development.
- Discuss the pericardium in detail with regard to its components, attachments and sinuses.
- Write notes on: (a) Interatrial septum, (b) Interventricular septum, (c) Right ventricle, (d) Tricuspid valve, (e) Mitral valve, (f) Conducting system of the heart, (g) Coronary blood supply, (h) Coronary dominance.

HEART

The heart (along with its covering, the pericardium) is the most important constituent of the mediastinum. It also is the primary organ of the cardiovascular system. It is pertinent to recollect facts about the heart and the cardiovascular system, before a detailed study is embarked upon.

The cardiovascular system consists of the ***heart*** and ***blood vessels***. The system is responsible for the circulation of blood through the tissues of the body. The heart acts as a pump and provides the force for this circulation. Blood, which is taken from the heart to the tissues by the ***arteries***, is brought back by the ***veins***. The largest artery is the ***aorta***. Arising from the heart, it divides, like the branches of a tree, into smaller and smaller branches. The smallest arteries are called ***arterioles***. The arterioles end in a plexus of thin-walled vessels that permeate the tissues. These thin-walled vessels are the ***capillaries***. Oxygen, nutrition, waste products, etc., pass through the walls of capillaries from blood to tissue cells and ***vice versa***. In some organs, vessels which are somewhat different in structure from capillaries are found and are called ***sinusoids***. Blood from capillaries or sinusoids is collected by veins and carried back to the heart. Veins adjoining the capillaries are very small and are called ***venules***. Venules join together to form veins; smaller veins join together (like tributaries of a river) to form larger and larger veins. Ultimately, blood reaches two large veins, the ***superior vena cava*** and the ***inferior vena cava***, which pour it back into the heart. Blood reaching the heart through the veins has lost its oxygen to the tissues and is hence called ***deoxygenated***. A special set of arteries and veins circulate this blood through the lungs where it is again oxygenated. This circulation through the lungs, for the purpose of oxygenation of blood, is called the ***pulmonary circulation*** (Latin.pulmonos=lung)***,*** to distinguish it from the main or ***systemic circulation.*** Blood circulation of this type, where the blood does not directly come into contact with the tissues, but oxygen and nutrients filter out through the walls of the capillaries is called ***closed circulation***.

The heart is a muscular pump designed to ensure the circulation of blood through the tissues of the body. Both structurally and functionally, it consists of two halves namely right and left. The ***right heart*** circulates blood only through the lungs for the purpose of oxygenation (i.e., through the pulmonary circulation). The ***left heart*** circulates blood to tissues of the entire body (i.e., through the systemic circulation). Each half of the heart consists of an inflow chamber called the ***atrium*** (atrium=entrance or way), and an outflow chamber called the ***ventricle*** (venter=hollow belly). The right and left atria are separated by an ***interatrial septum.*** The right and left ventricles are separated by an ***interventricular septum***. The right atrium opens into the right ventricle through the ***right atrioventricular orifice.*** This orifice is guarded by the ***tricuspid valve*** (Fig. 7.1).

The left atrium opens into the left ventricle through the ***left atrioventricular orifice***. This orifice is guarded by the ***mitral valve***. Both the tricuspid and mitral valves allow flow of blood from atria to ventricles, but not in the reverse direction. Each chamber of the heart is connected to one or more large blood vessels. The right atrium receives deoxygenated blood from tissues of the entire body through the ***superior*** and ***inferior venae cavae.*** This blood passes into the right ventricle. It leaves the right ventricle through a large outflow vessel called the ***pulmonary trunk.*** This

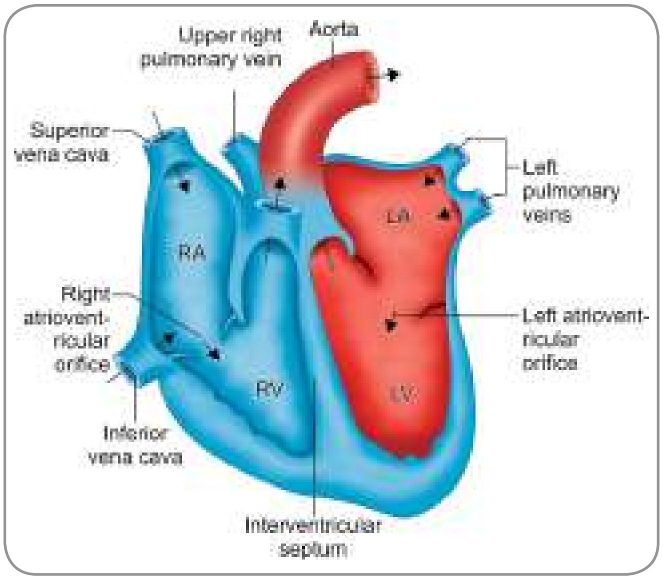


Fig. 7.1: Schematic diagram of the heart to show its chambers and their communications

Key: **RA.** Right atrium **RV.** Right ventricle **LA.** Left atrium **LV.** Left ventricle

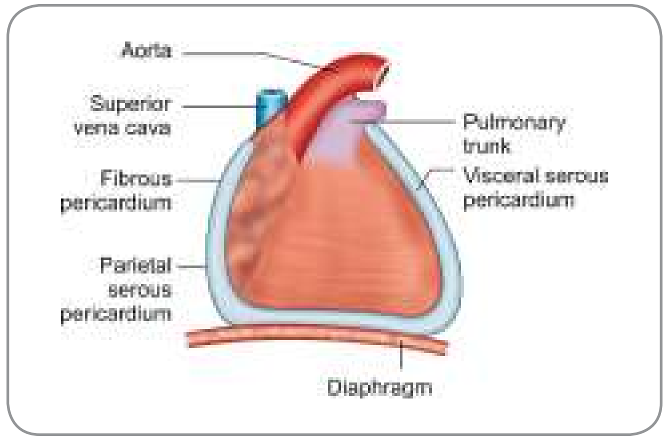


Fig. 7.2: Diagram to show layers of pericardium

trunk divides into right and left ***pulmonary arteries*** which carry blood to the lungs. Oxygenation takes place in the lungs. Blood oxygenated in the lungs is brought back to the heart by four ***pulmonary veins*** (two right and two left) which end in the left atrium. This blood passes into the left ventricle. The left ventricle pumps this blood into a large outflow vessel called the ***aorta***. The aorta and its branches distribute blood to tissues of the entire body. From the tissues, blood is then returned to the right atrium of the heart through the venae cavae, thus completing the circuit.

Location and Orientation of the Heart

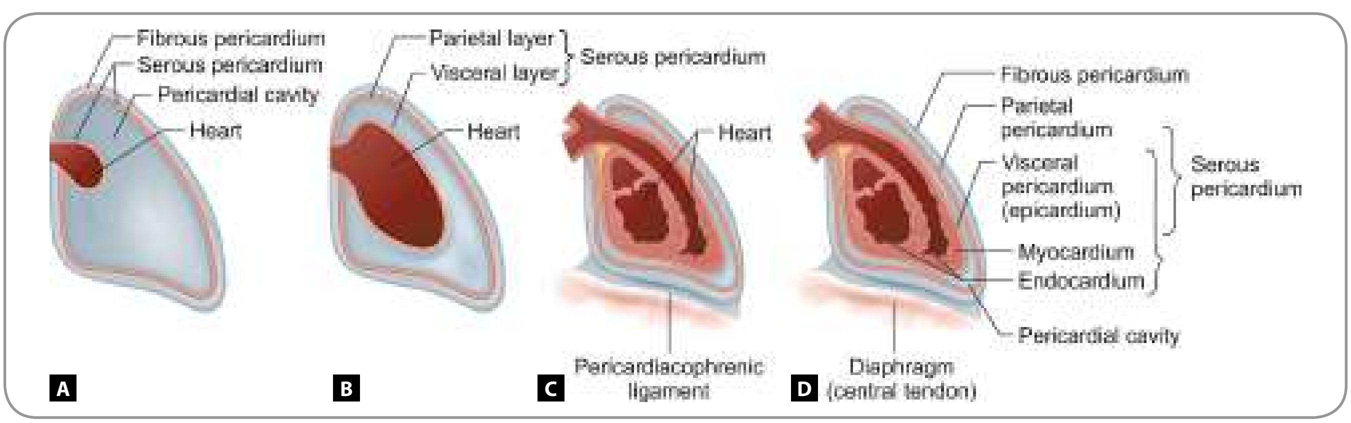
The heart is the largest organ of the mediastinum and is the size of a fist. Being cone shaped, it weighs about 250 to 350 grams. Situated posterior to the sternum and costal cartilages, and resting on the superior surface of the diaphragm, the heart assumes an oblique position within the thorax, with the apex lying to the left of midline and anterior to the rest of the heart. As the apex is anteriorly placed, the base of the heart is its posterior surface.

PERICARDIUM

The pericardium (Greek.peri=around, kardia=heart) is a fibro-serous bag covering the heart and the roots of great vessels. It is located in the middle mediastinum, behind the body of sternum and the 2nd to 6th costal cartilages. Posterior to it are the bodies of 5th to 8th thoracic vertebrae.

Components

It has an outer fibrous sac called the ***fibrous pericardium*** and an inner serous sac called the ***serous pericardium***. The heart and the roots of great vessels lie inside the fibrous pericardium and invaginate into the serous pericardium. There are two consequences to this invagination: (1) The ***serous pericardium*** comes to have two layers (Fig. 7.2), namely, the ***parietal and visceral layers***, while the fibrous pericardium has only one layer; (2) Though inside the ***fibrous pericardium***, heart is outside the pericardial cavity of the ***serous pericardium*** (Fig. 7.3).



Figs 7.3A to D: Development of heart and its invagination into the pericardial sac

Fibrous Pericardium

The fibrous pericardium can be described as a bag surrounding the heart and the roots of the great vessels which either come out or go to the chambers of the heart. Thus the roots of the aorta (coming out of the left ventricle), pulmonary trunk (coming out of the right ventricle), superior and inferior vena cavae (going to the right atrium) and pulmonary veins (going to the left atrium) lie within it. It is cone-shaped with an inferior base and a superior apex.

Extent

Vertically and in the median plane, it is co-extensive with the body of sternum, i.e., it extends from the manubriosternal joint to the xiphisternal joint. From the summit, the left border curves downward and laterally to reach the apex of the heart. The right border is less oblique and curves downward. As the aorta ascends up from the left ventricle, it carries the fibrous pericardium along with it to the level of the ***sternal angle***. The superior end of the fibrous pericardium, therefore, is at the level of the sternal angle and appears like a rounded summit.

Attachments

Superiorly, it is continuous with the fibrous tissue covering the ***aorta*** and the ***pulmonary trunk*** and blends with the pretracheal layer of deep cervical fascia. Inferiorly, it blends with the central tendon of the diaphragm and hence is broad. Anteriorly, it is attached to the superior and inferior ends of the body of sternum by the superior and inferior sternopericardial ligaments.

Relations

- ***Anteriorly:*** (1) Anterior margins of lungs and pleural cavities, (2) Anterior wall of thorax.
  On the left side, below the level of 4th costal cartilage, pericardium comes in direct contact with the internal surface of the body of sternum because the anterior margins of left lung and pleura deviate away from the midline.
- ***Posteriorly:*** (1) Right and Left bronchi, (2) Oesophagus and the oesophageal plexus of nerves, (3) Aorta and thoracic duct, (4) Azygos and Hemi azygos veins and (5) Mediastinal surfaces of right and left lungs.
- ***Right and left sides:*** (1) Phrenic nerves and pericardiaco-phrenic vessels of right and left sides, (2) Mediastinal pleura and (3) Cardiac impression of right and left lungs.

On the left side, Ligamentum arteriosum and the left recurrent laryngeal nerve are immediately outside the left border.

- ***Inferiorly:*** (1) Diaphragm, (2) Left lobe of liver and fundus of stomach.

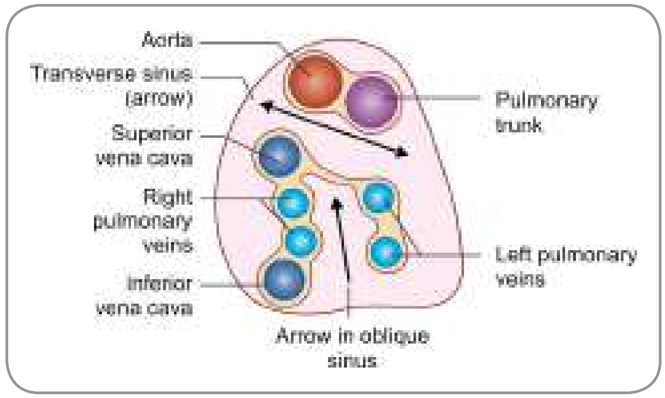


Fig. 7.4: Schematic drawing to show the relationship of the pericardial recesses to each other

Functions

As it is tough and strong, it holds the heart in place and also prevents its overfilling.

Serous Pericardium

The serous pericardium is thin and as already noted, has a ***parietal*** and a ***visceral layer***. It lies within the ***fibrous pericardium***. The parietal layer lines the internal aspect of the fibrous pericardium and together they are described as the outer layer of the ***pericardial sac*** (Fig. 7.4). The visceral layer is very closely applied to the heart and is often referred to as the epicardium. The ***parietal pericardium*** becomes continuous with the visceral layer around the roots of the great vessels. The space between the parietal and visceral layers is the ***pericardial cavity*** and contains the pericardial fluid which acts as a lubricant to reduce friction between the beating heart and the outer layer of the sac. About 50 ml of pericardial fluid is present in the cavity under normal circumstances.

The serous pericardium and the pericardial cavity serve as buffered containers for the heart to contract efficiently without friction.

Pericardial Sinuses

Due to folding and bending of the heart tube, two potential spaces come to exist in the ***pericardial cavity***. These are the pericardial sinuses. Due to folding, the receiving (venous) end and the distributing (arterial) end of the heart lie close to each other. The heart acquires a V-shape with the two limbs being more or less anterior and posterior.

A part of the pericardial cavity is trapped behind the V (posterior to the posterior limb) and is called the ***oblique sinus***. It is seen as the recess entrapped due to reflection of serous pericardium around the great veins. In the adult, it lies behind the left atrium and has boundaries as follows:

- ***Anteriorly***, the visceral serous pericardium covering the left atrium;

- ***Posteriorly***, the parietal serous pericardium lining the fibrous pericardium;
- ***Above***, the continuity of the parietal and visceral layers along the upper margin of the left atrium;
- ***To the left***, the continuity of the parietal and visceral layers along the upper and lower left pulmonary veins; and
- ***To the right***, the continuity of these layers along the superior vena cava, the upper and lower right pulmonary veins and the inferior vena cava. The sinus opens into the rest of the pericardial cavity below and to the left.

A pericardial recess also gets trapped between the two limbs of the V. This recess, known as the ***transverse sinus***, comes to occupy the gap between the pericardial reflection around the great arteries and the reflection around the great veins (Fig. 7.4).

These sinuses provide buffer space permitting contraction of different chambers of the heart. They have no other clinical significance.

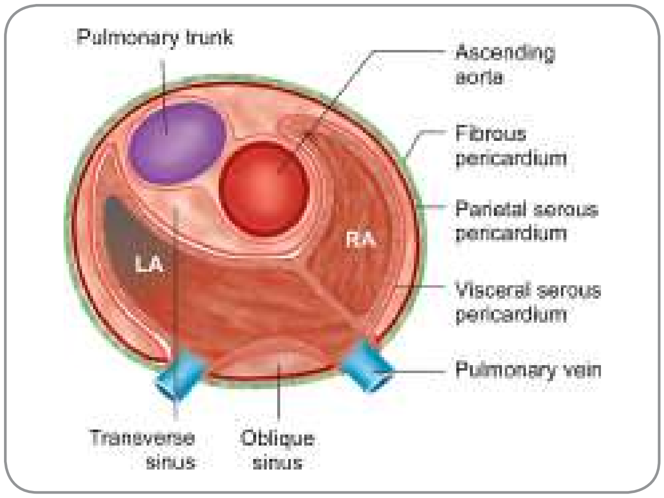


Fig. 7.6: Schematic transverse section through the upper part of the heart and pericardium

Key: LA. Left atrium **RA.** Right atrium

Development

In an early embryo which has undergone folding, the heart tube is formed dorsal to the ***pericardial bag***. The tube gradually invaginates into the bag, thus acquiring a pericardial covering (Fig. 7.5). As the invagination proceeds, the pericardial bag is compressed into a two layered covering, having the ***visceral*** and ***parietal layers***. Since the heart tube invaginates from the dorsal aspect, the line of connection between the visceral and parietal layers continues to be on the dorsal aspect and it appears as though the heart tube is suspended from the dorsal

contd…

Development *contd…*

part of the pericardium by a double layered structure. This double layered structure is the dorsal mesocardium. There is no ventral mesocardium. The heart tube elongates further. But the two ends of the tube (venous and arterial ends) are more or less fixed. So the heart tube folds and bends. The dorsal mesocardium, as a kind of preparation to the folding, breaks down. This breaking down leaves some space in the pericardial cavity and the space is between the venous end and arterial ends. This is the transverse sinus. Due to the folding and the two ends remaining close to each other, the heart acquires a V shape. A space is trapped behind the V and is called the ***oblique sinus*** (Fig. 7.6).

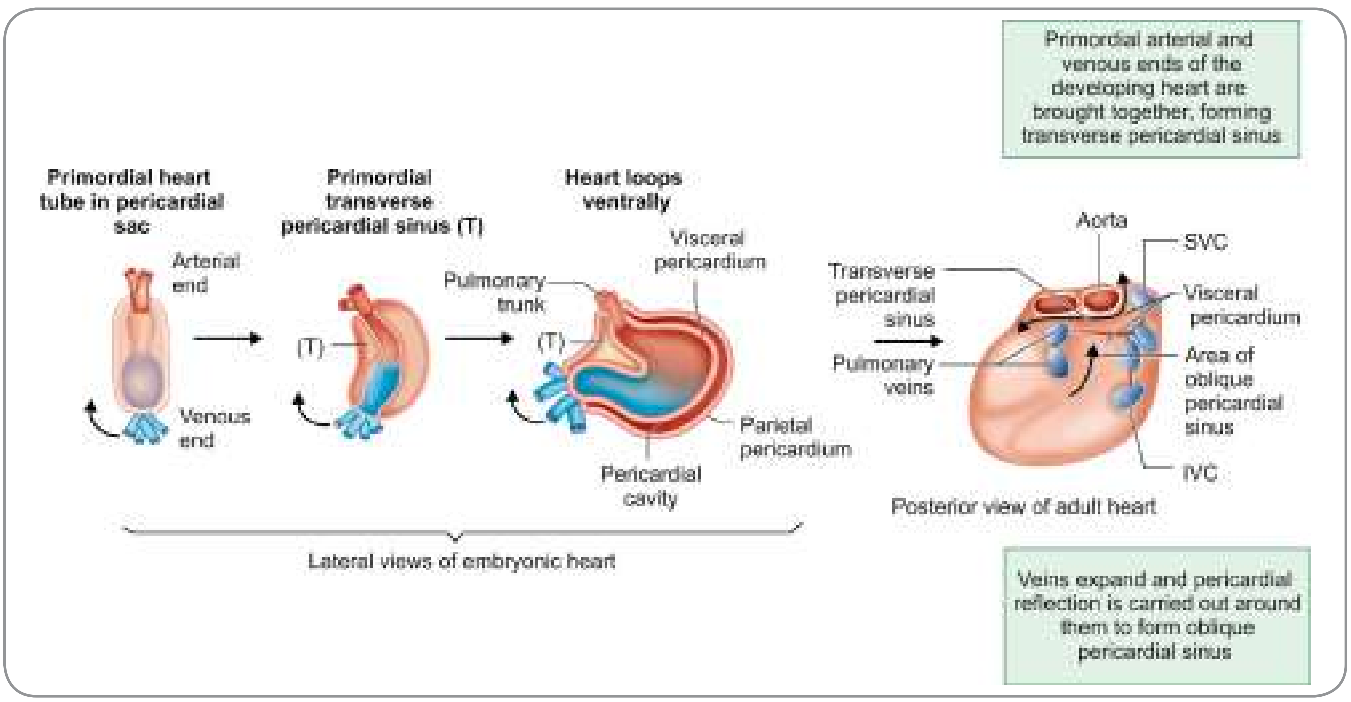


Fig. 7.5: Development stages to show formation of pericardial sinuses

BLOOD SUPPLY OF PERICARDIUM

Arterial Supply

Major blood supply to the fibrous pericardium and the parietal layer of the serous pericardium is derived from the pericardiacophrenic artery which is a branch of the Internal thoracic artery. Other arteries which contribute are the musculophrenic artery (branch of the internal thoracic artery), bronchial, oesophageal and superior phrenic arteries (all branches of the thoracic aorta).

The visceral layer of the serous pericardium is supplied by the coronary arteries.

Venous Drainage

The venous drainage of the pericardium is by the pericardiacophrenic veins (tributaries of internal thoracic veins) and also by tributaries of the azygos venous system.

Nerve Supply of Pericardium

The fibrous pericardium is supplied by twigs from the phrenic nerves. The parietal layer of the serous pericardium also derives its supply from phrenic nerves. The visceral layer is supplied by branches of sympathetic trunks and the vagus nerves (parasympathetic component).

Clinical Correlation

- Inflammation of pericardium is called ***pericarditis***. It may be acute or chronic. Pericardial fluid is secreted in excess due to inflammation. The pericardial cavity then gets filled with fluid leading to the condition called ***pericardial effusion***. The secretion may be so large that excess fluid may accumulate in the pericardial cavity compressing the thin walled atria and interfering with venous filling of the heart during diastole. This compression is aggravated by the inelasticity of the fibrous pericardium. Such compression is called ***cardiac tamponade*** (meaning ***'heart plug'***; plugging off the heart; Old French.tamponoule=a plug) and is a potentially fatal condition.
- Pericardial fluid can be drained by passing a needle immediately to the left of the xiphoid process (i.e., in the angle between the xiphoid process and left costal margin). The needle is passed upwards and backwards at an angle of 45 degrees. In this position, the needle does not injure the pleura or the lung. Such a process of aspirating pericardial fluid is called ***pericardiocentesis*** (Greek.kentesis, kenteo= puncture, to pierce).
- Haemopericardium is when blood collects in the pericardial cavity. Collection of blood may occur due to injuries, post operative bleeding or perforation of a weak myocardium, weakened by previous infarction. The condition is highly fatal because accumulation of blood is rapid and leads to high pressure. The heart is compressed and circulation fails. ***Pneumopericardium*** is the collection of air in the pericardial cavity. In patients with pneumothorax (where there is air in the pleural cavities), air cuts through connective tissue and enters the pericardial cavity.

contd...

Clinical Correlation *contd...*

- Normally, the opposing layers of visceral and parietal pericardium are smooth and do not cause any sound on coming into contact with/ rubbing against each other. In pericarditis, both the visceral and parietal layers become roughened due to the exudate. Rubbing of the layers against each other causes pericardial friction rub which is heard on auscultation. In ***chronic pericarditis***, which is usually due to tuberculosis, the pericardium may become very thick and may restrict movements of the heart. Surgical removal of the pericardium then becomes necessary.

LAYERS OF HEART WALL

The heart is a hollow pump. However, to function as a pump, its wall needs to be strong. The heart wall is composed of three layers—(i) ***a superficial epicardium***, (ii) ***a middle myocardium*** and (iii) ***deep endocardium***. The epicardium is actually the visceral pericardium that adheres to the heart. Though a serous membrane in early life, this layer gets gradually infiltrated with fat. The myocardium is the cardiac muscle layer and forms the bulk of the heart. This is the layer that actually contracts and makes the heart function as a pump. The cardiac muscle cells in the myocardial layer form bundles and these bundles are disposed in circular and spiral patterns which squeeze blood through and out of heart. The muscular portion is thinner in the atrial walls and thicker in the ventricular walls. The endocardium is a layer of endothelium resting on a thin layer of connective tissue. It is the layer that lines the heart chambers.

EXTERIOR OF HEART

It has already been noted that the heart lies within the bag of pericardium. In a plain anterior view, the heart appears to be trapezoidal. This appearance is taken into account in surface projection and in radiographic pictures of the heart. In reality (i.e., three dimensional) it is conical (or pyramidal) in shape. As it hangs like an inverted cone, it has an apex, a base and surfaces.

Surfaces of the Heart

The heart has three surfaces, namely, ***the sternocostal*** (or anterior) ***surface***, ***the posterior surface*** (base) and the ***diaphragmatic*** (or inferior) ***surface***. The right and left borders are slightly broader to warrant a description of right and left surfaces (right and left pulmonary surfaces) sometimes (Figs 7.7 and 7.9).

The ***sternocostal surface*** (Fig. 7.9) that lies posterior to anterior chest wall is formed (from right to left) by the right atrium, the right ventricle and the left ventricle. The contribution of the right ventricle to this surface is much greater than that of the left ventricle. The two ventricles are

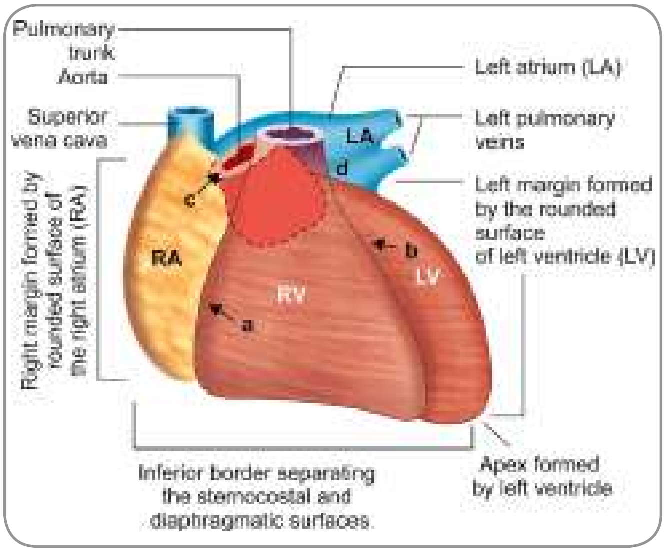


Fig. 7.7: Sternocostal surface of the heart in which the aorta and pulmonary trunk have been cut at their commencements to show the left atrium (LA) which is hidden behind them. The outline of the root of the aorta is shown in dots

Key: **a.** Atrioventricular groove **b.** Anterior interventricular groove **c.** Auricle of the left atrium

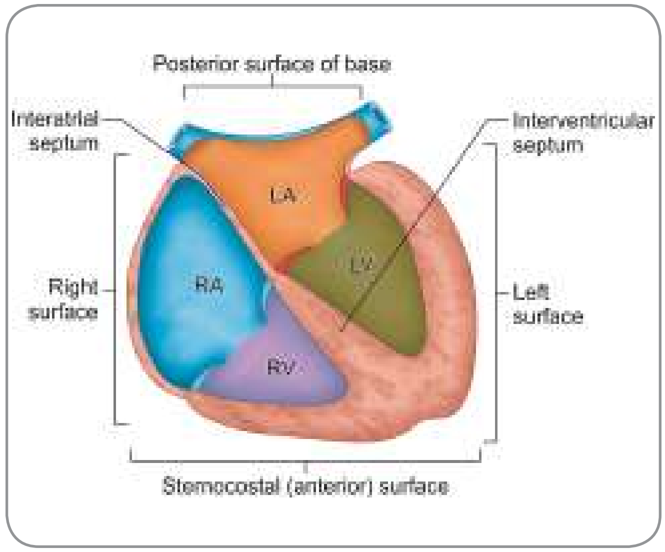


Fig. 7.8: Schematic transverse section through the heart

Key: **LA.** Left atrium **RA.** Right atrium **LV.** Left ventricle **RV.** Right ventricle

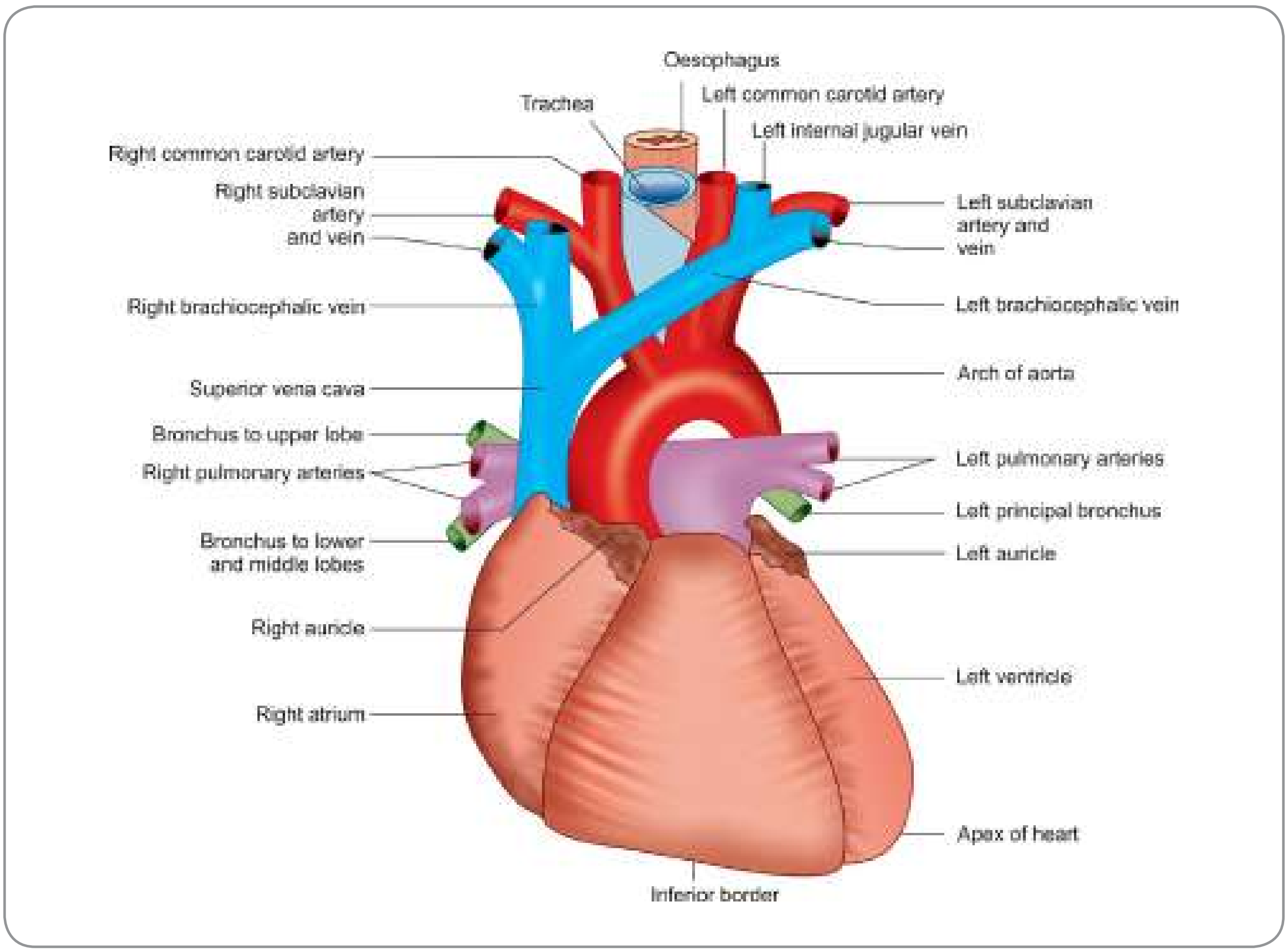


Fig. 7.9: Heart and superior mediastinum viewed from the front to show various chambers

separated by the ***anterior interventricular groove***. The right atrium and ventricle are separated by the anterior part of the ***atrioventricular groove*** which is also called the ***coronary sulcus***.

The ***sternocostal*** (or anterior) ***surface*** coincides with the trapezoidal shape of the heart's anterior projection. Thus, it shows four borders. It is bounded below by a sharp ***inferior border*** (Fig. 7.8) that separates it from the diaphragmatic surface. The region where the inferior border meets the left margin of the heart is called the ***apex***. The apex is formed by the left ventricle. The ***superior border*** of the heart is formed mainly by the left atrium. In the intact heart, this border is obscured from view by the parts of the aorta and the pulmonary trunk that lie in front of it. A small appendage (resembling a dog's ear) arises from the upper and anterior part of the right atrium and overlaps the right side of the lower part of the aorta. It is called the ***auricle of the right atrium*** (Latin.auris=ear). A similar appendage arising from the left atrium (***auricle of the left atrium***) overlaps the left side of the root of the pulmonary trunk (Fig. 7.9). This surface is formed predominantly by the right atrium and the right ventricle with the left ventricle contributing a little. The ***right border*** is formed of the right atrium. The ***left border*** is formed of the left atrium (more so, the auricle portion of the left atrium) and the left ventricle.

The ***diaphragmatic (or inferior) surface*** (Fig. 7.10) is formed in greater part (two-thirds) by the left ventricle, and to a lesser degree (one-third) by the right ventricle. The two ventricles are separated from each other by the ***posterior interventricular groove***. They are separated from the corresponding atria by the posterior part of the ***atrioventricular groove***. This surface is separated from the liver and stomach by the diaphragm.

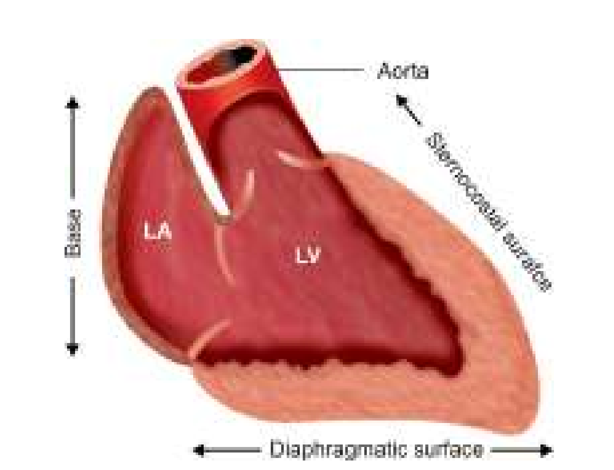


Fig. 7.10: Schematic vertical section, in an oblique plane, passing through the left half of the heart. Note the relationship of the sternocostal and diaphragmatic surfaces to each other

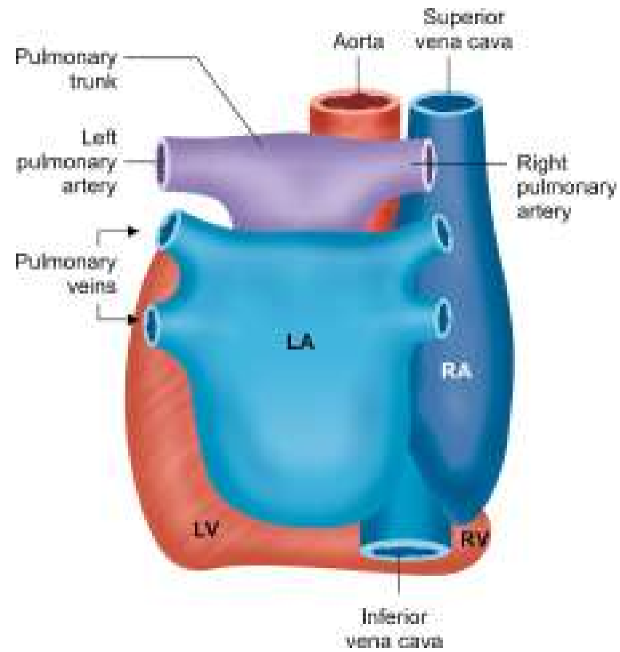


Fig. 7.11: Heart seen from behind to show its base

The ***posterior surface or base***, which extends from the bifurcation of the pulmonary trunk superiorly to the ***coronary sinus*** inferiorly, is formed mainly by the left atrium. A small part of it is formed by the posterior part of the right atrium.The left ventricle may also contribute very minimally. A line drawn vertically from the inferior vena cava to the two right pulmonary veins divides the surface into a larger left and a smaller right portions. The right and the left pulmonary arteries (Fig. 7.11) run along its upper margin and the coronary sinus is seen along its inferior margin. This surface is separated from the oesophagus, descending aorta and the lungs by pericardium. This is also the surface that receives the pulmonary veins on the right and left sides of its left atrial portion and the vena cavae on the superior and inferior ends of its right atrial portion.

Sulci of the Heart

The ***atrioventricular*** or ***coronary sulcus***, mentioned earlier, separates the atria from the ventricles. The complete sulcus forms a circle consisting of anterior and posterior parts. The right half of the anterior part is easily seen on the sternocostal surface. It runs downwards and to the right between the right atrium and the right ventricle.

The part of the sulcus separating the anterior aspects of the left ventricle and atrium is hidden from view by the aorta and pulmonary trunk. The posterior (or inferior) part of the sulcus lies at the junction of the diaphragmatic surface of the right ventricle with the right atrium and of the left ventricle with the left atrium. The anterior and posterior parts of the coronary sulcus become continuous with each other by curving around the borders of the heart.

The ***interventricular grooves*** mark the position of attachment of the ventricular septum to the outer wall of the heart.

The ***anterior interventricular groove*** separates the right and left ventricles on the sternocostal surface. The posterior groove (also called the ***inferior interventricular groove***) separates the same chambers on the diaphragmatic surface. The two grooves start at the apex of the heart. From here both grooves pass upwards, backwards and to the right on their respective surfaces and end by meeting the coronary sulcus.

Apex of Heart

The apex of the heart is formed by the inferolateral part of the left ventricle. It does not move throughout the cardiac cycle. It is also the point where the sounds of the mitral valve closure are best heard and this is referred to as the ***apex beat***. It lies immediately posterior to the fifth left intercostal space about a hand's breadth from the midline.

External Appearance of the Chambers

All the four chambers of the heart have distinct external appearances. The right atrium forms the entire right border. It has no outstanding external feature except for a prominent right auricle which projects as a flap from the anterosuperior aspect of the atrium. The right ventricle forms most of the anterior surface. The left atrium forms most of the posterior surface (base) of the heart. The triangular left auricle is visible on the anterior surface near the coronary sulcus. The left ventricle forms the apex of the heart and makes up most of the inferior surface.

INTERIOR OF HEART

Internally, two septa divide the heart cavity into ***four chambers***. These are the ***right*** and ***left atria*** and the ***right*** and ***left ventricles***. The heart is obliquely placed; so, the right atrium and the right ventricle lie anterior to the left atrium and the left ventricle respectively.

Interior of Right Atrium

The right atrium can be divided into two main parts: (1) the anterior part, or the ***atrium proper*** which is rough-walled; (2) the posterior part which is smooth-walled and is called the ***sinus venarum***. In addition, it has an appendage called the ***auricle***. The auricle arises from the upper and anterior part of the atrium proper, and is related to the right side of the ascending aorta.

The ***sinus venarum*** is derived, embryologically, from the ***sinus venosus***. All the large veins entering the right atrium open into this part. The opening of the ***superior vena cava*** is situated in its upper and posterior part, and that of the ***inferior vena cava*** in its lower part, close to the ***interatrial septum***. The opening of the superior venacava does not have a valve and the opening of the inferior vena cava is surrounded by a semilunar fold of endocardium called the ***valve of the inferior vena cava***. The sinus venarum presents a third opening called the ***orifice of the coronary sinus***. This opening is present just to the left of the opening of the inferior vena cava. It is also guarded by a valve, the ***valve of the coronary sinus***. In addition to these three major openings, there are numerous small apertures in the wall of the atrium for small veins called the ***venae cordis minimae***. Both the valves of the inferior vena cava and the coronary sinus are rudimentary and practically non functional (Fig. 7.12).

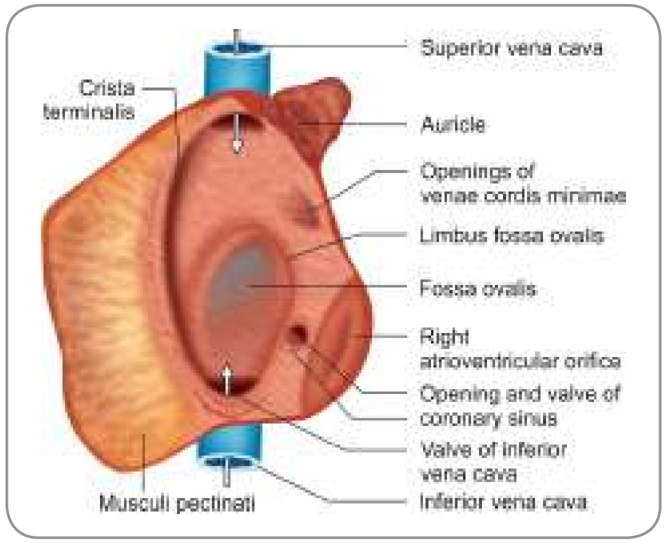


Fig. 7.12: Right atrium viewed from the right side after cutting its wall along its upper, anterior and inferior margins, and turning the flap backwards

The ***sinus venarum*** and the ***atrium proper*** meet along a line that runs more or less vertically on the lateral wall of the atrium. This line is marked, on the internal surface of the ***atrial wall***, by a muscular ridge called the ***crista terminalis*** (Fig. 7.12). The crista terminalis is actually a C-shaped ridge. It starts on the interatrial septum, passes anterior to the opening of the superior vena cava and runs along the lateral wall of the atrium to reach the opening of the inferior vena cava, where it becomes continuous with the valve of that opening. The position of the ***crista terminalis*** corresponds to a groove, the ***sulcus terminalis*** present on the external surface of the atrium.

The wall of the atrium proper shows the presence of a number of transversely running muscular ridges called the ***musculi pectinati (Latin.pecten=comb; the ridges give a comb like appearance)***. These ridges start from the crista terminalis and run forwards. Some of them enter the auricle where they form a network.

The right atrium is separated from the left atrium by the interatrial septum (Fig. 7.13). When viewed from within the

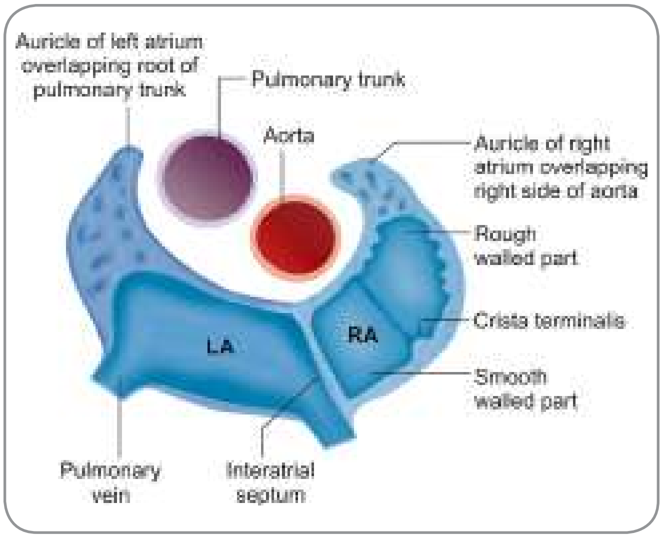


Fig. 7.13: Transverse section through the upper parts of the atria

right atrium, the septum shows certain features of interest and significance. On its lower part, is an oval depression called the ***fossa ovalis***. The upper margin of the fossa is thickened to form a curved ridge called the ***limbus fossa ovalis (or the annulus ovalis)***. The wall of the fossa ovalis is thin and represents the embryonic ***septum primum***. The limbus fossa ovalis represents the lower curved edge of the ***septum secundum***.

The right atrium opens into the right ventricle through the right atrioventricular orifice which is guarded by the tricuspid valve. When viewed from interior, the atrioventricular opening is anterior to the inferior venacaval opening.

Dissection

Study the prosected and isolated specimen of heart. Also, study the position of heart and its relations in a partially dissected specimen of the thoracic cavity. With a pair of thin pointed scissors, dissect the atriventricular and interventricular grooves of the heart specimen in your hand; locate the vessels in these grooves; observe and study their branches and course.

Locate the sulcus terminalis on the exterior of the right atrium. Make an incision about 1 cm anterior to and parallel to this sulcus. Open the right atrium and study its features. Similarly, make a window opening on the anterior aspect of the right ventricle and study the features. Feel the left atrium and compare its features with those of the right atrium. Repeat the same exercise with the two ventricles.

With the heart in situ in the thoracic cavity, review the features of pericardium.

Interior of Left Atrium

The left atrium is a thin walled cavity. Most of the wall is smooth. ***Musculi pectinati*** are present only in the auricle portion of the atrium. The cavity is separated from that of the right atrium by the interatrial septum.

The left atrium receives ***four pulmonary veins***, ***two right and two left***, from the corresponding lungs. These veins open into the upper lateral part of the atrium. The anteroinferior part of the atrium opens into the left ventricle through the left atrioventricular orifice which is guarded by the ***mitral valve***.

Development

In embryonic life there is one atrium, one ventricle and one atrioventriclar orifice. The atrioventricular orifice is divided into right and left parts by the appearance of anterior and posterior endocardial cushions which gradually grow towards each other. Their fusion forms the septum intermedium. Within the single atrial cavity, changes now occur. A partition starts at the posterosuperior aspect of the cavity and grows towards the septum intermedium. This is the septum primum. The gap between the two septa appears like a foramen and is called the ***foramen primum***. The septum primum ultimately fuses with the septum intermedium thus obliterating the foramen primum. The primitive atrium now has been divided into right and left chambers. The lungs have not started working in the embryo and there is necessity for the blood to reach the left side of the atrium bypassing the right ventricle—lungs pathway. To facilitate this, just before the fusion of the septa, the upper part of the septum primum breaks down forming the foramen secundum. Blood flows through this second foramen from right to left. A new septum now starts from the posterosuperior aspect of the right chamber (that is to the right of the septum primum). This is the septum secundum. The inferior margin of the septum secundum is crescentic with the concavity downwards. It grows towards the septum intermedium and fuses with tvhe latter by the prolonged limbs of its crescent. This causes an oval opening between the septum secundum and the septum intermedium which is called the ***foramen ovale***.

Passage between the two atrial chambers is now established through the foramen ovale. However, the system does not function as a simple opening. It is seen that the septum primum and the septum secundum are placed adjacent to each other. The upper part of the septum primum has an opening (foramen secundum) but the upper part of the septum secundum has none. So this opening is overlapped by the septum secundum. Opposite the foramen ovale is the lower part of the septum primum. However, this septum is thinner when compared to the second septum. As blood flows in the embryo into the right chamber, the left chamber is empty and so has lower pressure. Suction force is created on the left side. The septum secundum is firm but the septum primum is not. So blood flows through the ***foramen ovale*** and pushes the septum primum like a flap and enters the left chamber. Thus an oblique passage—foramen ovale-septum primum-foramen secundum—is created to establish unhindered circulation.

This mechanism continues until birth. At birth, as the newborn breathes through lungs, blood is returned to the heart through the pulmonary veins which reach the left atrium.

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Development ***contd…***

Pressure of blood on the left side is now increased. Equalisation of pressure on both sides causes the septum primum flap to adhere to the septum secundum.

The original foramen ovale appears as a depression(fossa ovalis) in the atrial septum and the floor of the depression is formed by the septum primum. The thickened crescentic margin of the foramen forms the limbus fossa ovalis.

Interatrial Septum (Fig. 7.14)

This is also called ***atrial septum***, the interatrial septum, as its name reveals is a partition between the two atria. It prevents mixing of blood between the two chambers. As already seen, it has an oval depression called the ***fossa ovalis*** and a thickened ridge along its upper border. The fossa ovalis itself is a remnant of the embryonic foramen ovale.

Clinical Correlation

Congenital Atrial Septal Defects

- As the interatrial septum has a complicated developmental history, defects of the septum are common. They lead to abnormal flow of blood from the left atrium to the right atrium(oxygenated blood from the left admixing with deoxygenated blood in the right side). The effects are that the pulmonary circulation is overloaded and the left ventricle has to work harder and undergoes hypertrophy. If untreated, the condition can end in cardiac failure.

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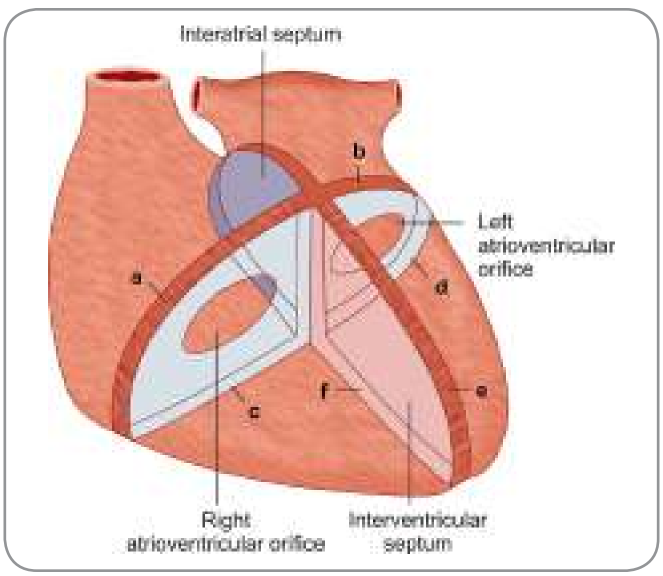


Fig. 7.14: Schematic drawing to show the positions of the interventricular and atrioventricular junctions. The drawing is made as if the walls and septa of the heart were transparent

Key: a, b, c, d Shows the atrioventricular junction **e, f** Shows the interventricular junction

Clinical Correlation ***contd...***

- The simplest of the defects is the one in which the septum primum and septum secundum have formed normally but have failed to fuse leading to a ***patent foremen ovale*** after birth. Such a defect may be of no functional significance; the defect is actually a linear gap between the two septa and may get obliterated spontaneously as the child grows. About 15 to 20 percent adults do have a probe sized patency in the upper part of the fossa ovalis and have no functional or haemodynamic abnormality.
- In the most common variety, the lower part of the septum secundum is not properly formed leading to a central defect in the interatrial septum. This is referred to as ***septum secundum defect***.
- In a ***septum primum defect***, the lower part of the septum primum fails to fuse with atrioventricular endocardial cushions. This defect is, therefore, seen in the lower part of the interatrial septum.
- A defect high up in the interatrial septum may be caused by defective incorporation of the sinus venosus into the atrium.

The various varieties of atrial septal defect can be treated by various forms of surgeries.

Interior of Ventricles

The cavities of the right and left ventricles have some features in common (Fig. 7.15). Each ventricle has an ***inflow part*** beginning just in front of the corresponding ***atrioventricular orifice***, and extending forwards and to the left i.e., towards the apex of the heart. The cavity then turns sharply upwards to form the ***outflow part***.

The inflow part of each ventricle has a rough inner surface due to the presence of internally projecting bundles of cardiac muscle called ***trabeculae carneae (Latin.carnea=flesh)***. The trabeculae carneae are of three types: (1) the simple ones are plain ridges (elevations from the wall); (2) the second set are those which are attached at their ends to the wall, but free in the middle (bridges), (3) the third group consists of the papillary muscles (pillars),

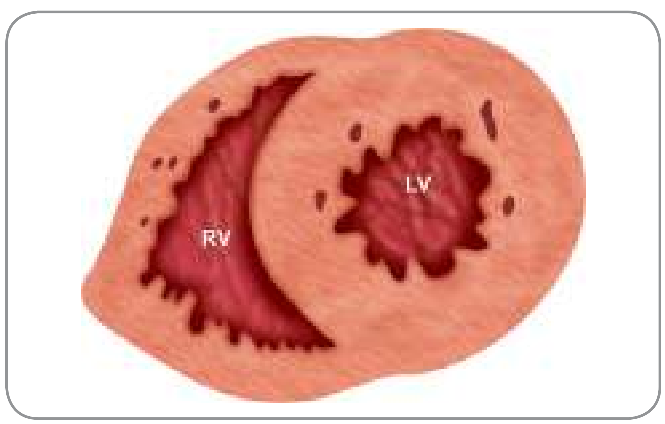


Fig. 7.15: Transverse section across the ventricles near the apex of the heart

Note: Differences in thickness of wall and in shape of cavity these are finger-like processes attached to the ventricular wall at one end, but free at the other; the free conical ends are connected to the atrioventricular valves through the ***chordal tendineal***.

In contrast to the rough walls of the inflow parts, the outflow parts of both the ventricles are smooth.

Interior of the Right Ventricle

The right ventricle, at its receiving end communicates with the right atrium through the right atrioventricular orifice and at its distributing end with the pulmonary artery through the pulmonary valve. In that part of the cavity which continues from the atrioventricular orifice, are seen the trabeculae carneae and the papillary muscles. One of the bridges which is attached to the wall at the ends and free in the middle forms the ***moderator band***. This band stretches from the septal wall to the anterior wall of the ventricular cavity. It conveys the right branch of the atrioventricular bundle that is part of the conducting system.

As the ventricular cavity is traced to its outflow area, it is funnel shaped and is then called the ***infundibulum***. The upper end of the infundibulum opens into the pulmonary trunk through the pulmonary valve.

The inflow and outflow parts make an angle of about ninety degrees with each other. The upper part of their junction is marked by a prominent bulging of myocardium called the ***supraventricular crest***.

Interior of the Left Ventricle

The left ventricle, at its receiving end communicates with the left atrium through the left atrioventricular orifice and at its distributing end with the aorta through the aortic valve. In that part of the cavity which continues from the atrioventricular orifice, are seen the trabeculae carneae and the papillary muscles. The walls are three times thicker than those of the right ventricle, since the left ventricle has to hold blood which is at a pressure that is six times higher than that of the right ventricle and push the blood through the systemic circulation. The trabeculae carneae and the papillary muscles are well developed, finer and more numerous but there is no moderator band.

The outflow part of the left ventricle is called the ***aortic vestibule***. Being smooth walled and non muscular, it becomes continuous with the ascending aorta through the aortic valve. The aortic vestibule forms an acute angle with the inflow part, running sharply upwards and to the right to reach the aortic orifice. It crosses behind the infundibulum from left to right. This explains how the aortic orifice comes to lie to the right of the pulmonary orifice.

If a section across the lower parts of the two ventricles is studied, it can be seen that walls of the left ventricle are much thicker than those of the right ventricle. In addition, the outline of the left ventricle is roughly circular and that of the right ventricle is crescentic. This is because of the interventricular septum bulges into the right ventricle so that its right surface is convex, and its left surface is concave.

The cavity of the right ventricle is triangular in shape and that of the left ventricle is conical. The entry points of the ventricles (or the atrioventricular orifices) are posterior in position; the exit points (or the pulmonary or aortic orifices) are anterosuperior. So, the flow of blood inside each ventricle is V-shaped. In each ventricle, the exit point is on the septal side of the entry point.

Development

The heart develops from a tubular structure. A series of constrictions and dilatations give rise to the chambers of sinus venosus, primitive atrium, primitive ventricle and bulbus cordis. The junction between the primitive ventricle and the bulbus cordis is marked externally by a groove called the ***bulboventricular groove***. Internally it is narrow and will form the primary interventricular foramen. As development proceeds, these dilatations undergo various kinds of bending and folding, so that the primitive ventricle and the proximal third of the bulbus come to lie side by side. Both these chambers get trabeculated. By the fourth week of intrauterine life, the two chambers enlarge in size. This happens by growth of myocardium on the outer aspect and breaking down of the trabeculae on the inner aspect. The primitive ventricle will become the left ventricle and the proximal bulbus will become the right ventricle. As the chambers keep expanding, their medial walls appose each other and fuse. This forms the muscular interventricular septum. Between the upper part of the muscular septum and the inferior aspect of the septum intermedium is a gap which forms a communication between the two ventricles and hence is called the ***interventricular foramen***.

Meanwhile the distal two thirds of the bulbus (middle third forms the conus cordis giving rise to the outflow tracts of both ventricles and the distal third forms the truncus arteriosus giving rise to the great arteries) develop the conus septum. Completion of the conus septum makes the interventricular foramen appear smaller. Subsequently, tissue elongation from the anterior endocardial cushion (anterior part of the septum intermedium) occurs along the upper border of the muscular septum. This tissue abuts on the proximal part of the conus septum and closes the foramen. The membranous part is thus formed by contribution from the endocardial cushion and the conus septum.

Interventricular Septum (Fig. 7.14)

Otherwise called the ***ventricular septum***, the interventricular septum separates the right and the left ventricular chambers. *In situ*, it is obliquely placed with the right surface facing forwards and to the right and the left surface facing backwards and to the left. The posterosuperior portion separates the two AV orifices and the anteroinferior portion reaches the apex. It has the muscular and membranous parts. The muscular part has the thickness of the wall of the left ventricle and bulges into the right ventricular cavity. The membranous part is posterosuperior. On the right side, the septal cusp of the tricuspid valve is attached in the middle of the membranous septum. The portion of the membranous septum below this attachment is truly between the two ventricles and so is interventricular; but the portion above the attachment is between the right atrium and left ventricle and so is atrioventricular.

Clinical Correlation

- ***Congenital ventricular septal defect:*** An isolated defect of the muscular part of the ventricular septum is a common cardiac anomaly seen at birth. In many cases, the defects disappear spontaneously by about one year of age, and some even later.
  The membranous septum has a complicated development. So, it is prone to more defects. Since it is close to the aortic and pulmonary orifices, ventricular septal defects are often found in association with abnormalities of these orifices. The physiological effects are those of a left-right shunt leading to excessive pressure in the pulmonary circulation (***pulmonary hypertension***), and excessive load on the left ventricle eventually leading to cardiac failure.
  The defect can be corrected by surgical intervention.
- ***Fallot's tetralogy:*** This is a congenital anomaly that involves the conotruncal bulbar region. The conus septum is anteriorly displaced and results in unequal division of the outflow areas. Four alterations occur and hence the name ***tetralogy*** (tetra=four). The four features that make up the tetralogy are:
  1. Interventricular septal defect.
  2. Pulmonary stenosis.
  3. Aortic opening over-rides the free upper edge of the ventricular septum. In other words, the aorta communicates with both the right and left ventricles.
  4. Hypertrophy of the wall of the right ventricle.

  The unequal division is responsible for one outflow (pulmonary) becoming narrow and stenosed and the other (aortic) overlapping the right ventricle. The right ventricle has more load because it has to pump into the aorta and also into a narrowed pulmonary artery. So, it hypertrophies. Surgical treatment of ***Fallot's tetralogy*** aims ideally at complete correction of all defects. Shortage of blood flow into the lungs can be increased by anastomosing the aorta or one of its branches to the pulmonary artery. One mode of surgical treatment is that described by Blalock, in which the left subclavian artery is anastomosed to the left pulmonary artery.
- ***Other defects:*** Several types of defects related to the development of the ventricular and conus septa can occur.
  - ***Persistent truncus arteriosus:*** The conotruncal septum does not develop at all; so, the bulbus, conus and truncus remain undivided; there is no formation of aorta and pulmonary trunk. The outflow tract remains single. Since the conotruncal septum contributes to the interventricular septum, the latter is also defective.
  - ***Transposition of great vessels:*** The conotruncal septum fails to have a spiral disposition; it joins the ventricular area straight. So the pulmonary trunk gets connected

contd…

Clinical Correlation *contd…*

to the left ventricle and the aorta to the right ventricle. Membranous part of the ventricular septum is also defective.
  - ***Valvular stenosis:*** The semilunar valves of either the aorta or the pulmonary trunk are defective leading to narrowing of the concerned vessel.

Atrioventricular Orifices (Fig. 7.14)

The openings through which the atria communicate with the ventricles are the atrioventricular orifices. Both the right and the left are oval apertures. The orientation of the apertures relative to the chambers of the heart is important. The openings lie in a plane that is almost vertical, with a slight downward inclination. Each opening, therefore is directed forwards, to the left, and slightly downwards.

Each orifice is strengthened by the presence of a variable amount of fibrous tissue around and is guarded by a valve that allows flow of blood from atrium to ventricle and not in the reverse direction. The valves are made up of thin leaflets of tissue called ***cusps***. The number of cusps present in a valve decides its name and so we have the ***tricuspid (three cusped) and the bicuspid (two cusped) valves***.

Development

At the region of the single atrioventricular orifice, endocardial proliferation from the anterior and posterior walls of the orifice occurs. These grow towards each other and fuse to partition the single orifice into right and left orifices. Now, each orifice is surrounded by local proliferation of mesenchymal tissue. As blood is flowing in and out of the chambers, the ventricular aspect of these mesenchymal proliferations are hollowed and thinned out. Thus valves are formed and they are connected to the walls by muscular cords. Gradually, muscular tissue degenerates and the cords become fibrous. These cords become the chordal tendineal. The ventricular walls are trabeculated and these trabeculae form the trabeculae carneae and the papillary muscles. On the right side three valve leaflets are formed and on the left, two.

Each cusp consists of a double fold of endocardium within which there is some fibrous tissue. It has a ventricular surface and an atrial surface. In addition, each cusp has a base which is attached to the ring of fibrous tissue around the atrioventricular orifice. Since the shape of a cusp is more or less triangular, it also has an apex and free margins. The margins of adjoining cusps may be fused to each other for some distance so that the cusps may in effect form a continuous membrane. The apex and margins of the cusps give attachment to delicate tendinous strands called the ***chordae tendineae*** (Fig. 7.16). The chordal tendineal are also attached to the ventricular surfaces of the cusps which

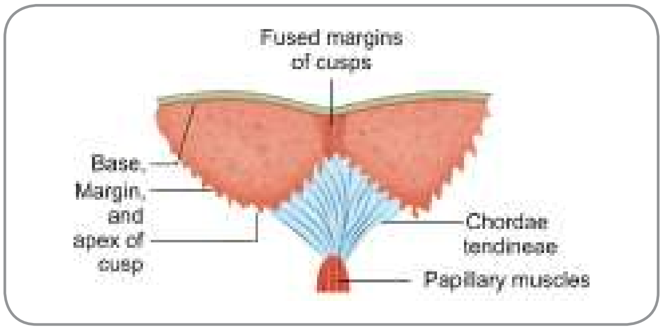


Fig. 7.16: Schematic surface view to show the relationship of cusps to the atrioventricular ring, the chordal tendineal and a papillary muscle

are, therefore, rough in contrast to the atrial surfaces which are smooth. At their other end, the chordal tendineal are attached to the apices of papillary muscles.

Each papillary muscle is attached (through the chordal tendineal) to adjoining parts of two cusps. As a result, the adjoining margins of the two cusps are drawn together when a single papillary muscle contracts.

The right atrioventricular orifice is larger than the left. It is said to be large enough to admit the tips of three fingers. In contrast, the left orifice is said to admit only two fingers.

Tricuspid Valve

As its name implies, this valve which guards the right atrioventricular orifice is made up of three cusps. These cusps have traditionally been designated as ***anterior***, ***septal*** and ***posterior*** (Fig. 7.17).

The orientation of the orifices needs to be remembered now. If the orifices are imagined to be placed on the horizontal plane between superiorly placed atria and inferiorly placed ventricles, then the margins of the orifices will have anterior, posterior and medial parts. However, since the orifices are obliquely placed, the anterior part becomes superolateral and the posterior part becomes inferolateral (Fig. 7.18).

Thus, the anterior cusp is attached to the anterior or the superolateral margin of the orifice and the posterior cusp to the posterior or the inferolateral margin. The septal cusp is attached to the medial margin.The anterior cusp separates the inflow part of the right ventricle from the infundibulum.

The chordal tendineal attached to the cusps of the tricuspid valve arise from: (a) a large anterior papillary muscle, (b) a large posterior papillary muscle and (c) directly from the interventricular septum or from small papillary muscles attached to the septum. The ***chordal tendineal*** arising from the ***anterior papillary muscle*** are attached to the ***anterior and posterior cusps***; those from the ***posterior muscle*** to the ***posterior and septal cusps***; and those from the ***septal muscles*** to the ***septal and anterior*** cusps (Fig. 7.18).

The base of the anterior muscle is attached to the ***sternocostal wall*** (Fig. 7.19) of the right ventricle (and so the name anterior).

The base of the posterior muscle is attached near the angle between the diaphragmatic wall and the interventricular septum (which makes its position posterior and so the name). The septal papillary muscles are attached to the interventricular septum. The base of the anterior papillary muscle is connected to the interventricular septum by a special band of cardiac muscle called the ***septomarginal trabecula*** (also called the ***moderator band***) (Fig. 7.18).

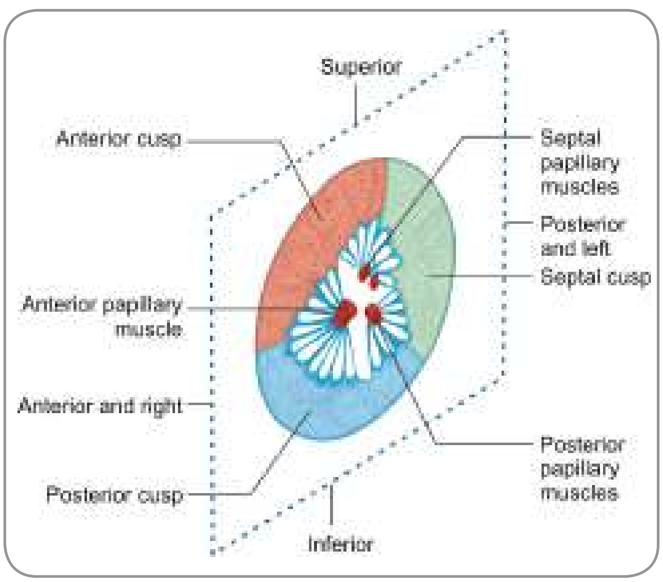


Fig. 7.17: Scheme to show the cusps and papillary muscles of the tricuspid valve

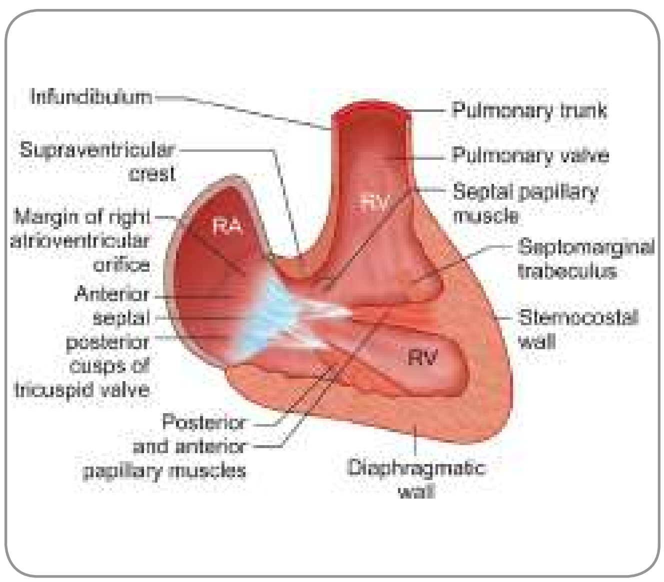


Fig. 7.18: Schematic diagram to show the main features in the interior of the right ventricle

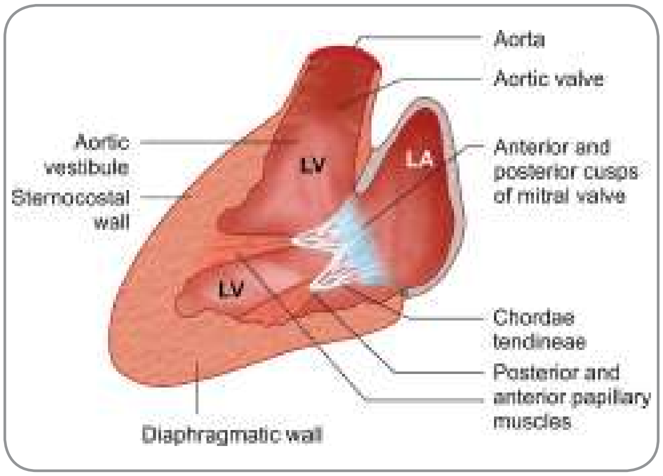


Fig. 7.19: Schematic diagram to show the main features in the interior of the left ventricle

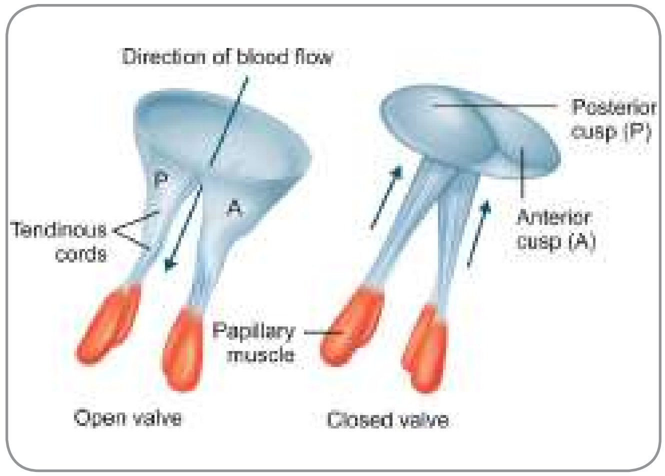


Fig. 7.21: Attachments of papillary muscles to the cusps of valves

Mitral Valve

The mitral valve has the same basic features as those of the tricuspid valve. It has two cusps namely ***anterior*** and ***posterior*** (Fig. 7.20).

The 'anterior' cusp (which is larger than the posterior cusp) is attached to the upper-right part of the margin of the left AV orifice (which makes it the superomedial part of the margin; the septum forms the 'midline' and towards/closer to the septum becomes 'medial'). The 'posterior' cusp is attached to the lower-left part (which is the inferolateral part; 'left' of left ventricle is away from septum).

The anterior cusp intervenes between the mitral and aortic orifices. As a result, there is forceful blood flow along both surfaces (atrial and ventricular) of this cusp. In keeping with this fact both surfaces of this cusp are smooth, nearly all the ***chordal tendineal*** being attached at or near the margin of the cusp (and not on the ventricular surface as in the posterior cusp, or in the cusps of the tricuspid valve).

The ***papillary muscles*** (Fig. 7.21) connected to the cusps of the mitral valve are also termed anterior and posterior.

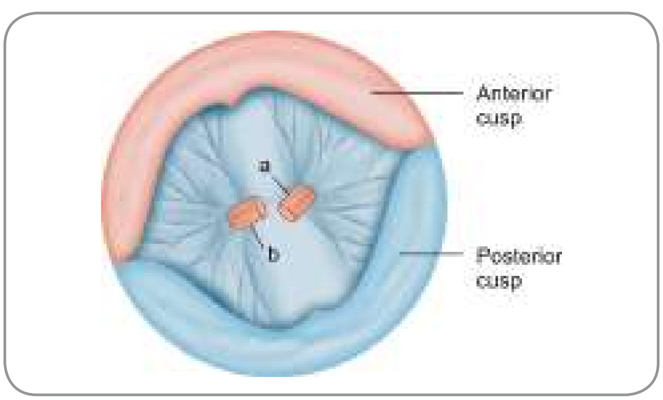


Fig. 7.20: Scheme to show the cusps and papillary muscles of the mitral valve
Key: a. Anterior papillary muscle **b.** Papillary muscle

The anterior muscle arises from the sternocostal wall of the ventricle near its lower end. The posterior muscle arises from the diaphragmatic wall near its anterior end. The origins of the two papillary muscles are close together. The two muscles run backwards almost parallel to each other, the 'anterior' muscle being placed to the left of and slightly above the 'posterior' muscle.

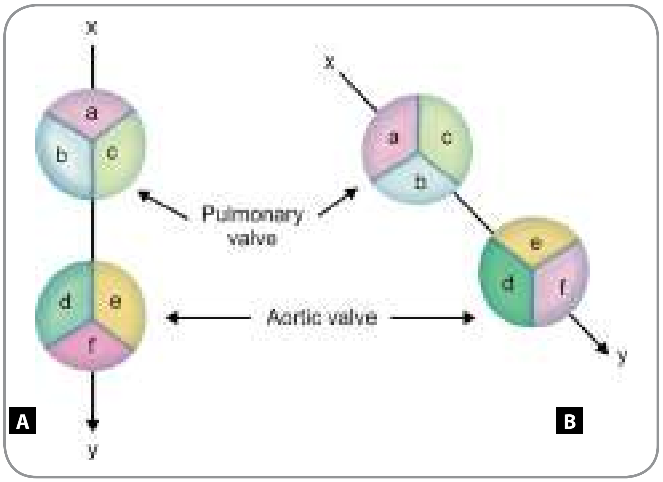
The chordal tendineal arising from each papillary muscle pass to adjoining parts of the two cusps of the mitral valve. Those of the anterior muscle pass to the left half of each cusp and those of the posterior muscle to the right half.

Pulmonary and Aortic Orifices

These orifices are located at the upper ends of the outflow parts of the right and left ventricles respectively. Each orifice is circular. The pulmonary orifice is somewhat larger than the aortic orifice, the diameters of the orifices being about 3 cm and 2.5 cm respectively. The pulmonary orifice is placed above and to the left of the tricuspid orifice, the aortic orifice intervening between them (septal side of the right ventricle is left). The aortic orifice is placed in front and to the right of the mitral orifice (septal side of the left ventricle is right). The pulmonary orifice is guarded by the ***pulmonary valve*** and the aortic orifice by the ***aortic valve*** (Figs 7.22A and B).

Each valve consists of three semilunar cusps. Each cusp is roughly triangular. It has a convex lower edge that is attached to a part of the margin of the orifice. It also has two free margins that meet at the apex of the cusp. Each cusp consists of a double fold of endocardium with some fibrous tissue enclosed in it. The region of the apex is thickened to form a ***nodule***, while crescentic parts near the free edges, called the ***lunules***, contain very little connective tissue.

Since the convex lower margins are attached to the walls of the concerned vessel, the open mouths of the cusps are directed upward into the vessel lumen. Because of the



Figs 7.22A and B: Position of cusps of pulmonary and aortic valves **A.** Before rotation **B.** After rotation

attachment of the cusps to the vessel wall, no chordae or papillary muscle is required to prevent the cusps from prolapsing into the ventricle.

At the root of the pulmonary trunk and the aorta, there are three dilatations called the ***sinuses*** (***pulmonary sinus*** or ***aortic sinus***); one sinus is situated external to each cusp. The coronary arteries arise from two of the aortic sinuses.

It is important to note the position of the three cusps of the pulmonary and aortic valves. In the foetus, the pulmonary valve lies directly in front of the aortic valve. It has one anterior cusp and two posterior cusps. The aortic valve has two anterior cusps and one posterior cusp. Subsequently, the aorta and pulmonary trunk undergo a rotation so that the pulmonary orifice comes to lie somewhat to the left of the aortic orifice. The rotation affects the position of the cusps. The pulmonary valve now appears to have one posterior cusp and two anterior cusps whereas the aortic valve appears to have one anterior cusp and two posterior cusps. However, it is customary to describe that the pulmonary valve has one anterior and two posterior cusps and the aortic valve has one posterior and two anterior cusps. The reason is embryologic.

Development

In the embryonic heart, the common truncus arteriosus has four cusps. Due to partitioning of the truncus, two vessels occur and the right and left cusps get subdivided into two each but with the names of right and left continuing. Meanwhile the heart undergoes rotation so that the apex is directed to the left. This causes rotation of the two vessels too and the cusps now come to lie in the rotated (final) position. However, the naming remains the same as that of their embryological origin and position. This naming can also be correlated to the coronary arteries. The right coronary artery arises from the right sinus that is superior to the right cusp and the left artery from the left sinus that is superior to the left cusp. The posterior sinus and cusp of the aorta do not give rise to any coronary artery; and so the cusp is non-coronary.

Added Information

- The bicuspid valve has been named the 'mitral' valve because of its resemblance to the head dress of a bishop. The head dress is called a ***miter*** and hence the term ***'mitral'***.
- The myocardium of the heart is in the shape of a large helix. There are two spirals. The outer spiral has horizontal bands of fibres. The inner spiral is apical, i.e., the fibres run from the atrioventricular area to the apex and then spirally ascend up. Because of the double spiral, ventricular contraction causes a wringing action. During most of systole, the outer spiral contracts causing narrowing and shortening of the chamber. This causes blood to flow out. In the latter part of systole, as the myocardium continues to contract, the inner apical spiral contracts. This causes the ventricular chamber to elongate. As diastole follows, there is a brief relaxation of the myocardium causing widening of the chambers. Both lengthening and widening lead to increase of the ventricular volume which in turn draws blood into the chambers.
- The inflow into both the ventricles is from the posterosuperior aspect. The outflow of blood in the right ventricle has to leave superiorly and to the left. So the blood takes a u-shaped route with a change of direction of about 135 to 140 degrees. This change of direction is brought about by the supraventricular crest. The crest directs the inflow into the cavity and the outflow into the infundibulum. In the left ventricle, the change of direction required is about 180 degrees. There is no separate partition or crest; but the anterior cusp of the mitral valve itself acts as the deflector and the reversal takes place around it.
- The pulmonary and aortic sinuses are small spaces between the dilatations in the wall of the corresponding vessel and the cusps of the semilunar valves. Though small, these sinuses have an important functional role. Blood in the sinuses and the widening caused by the dilatations prevent the valvular cusps from getting stuck to the walls. This is essential for normal closure of the valves which will not happen if the cusps are stuck.

Clinical Correlation

Endocarditis

Inflammation of the endocardium is referred to as ***endocarditis*** and that of the myocardium as ***myocarditis***. Bacterial endocarditis often follows rheumatic infection in childhood and can damage the cusps of valves. Most frequently it affects the mitral and aortic valves.

Auscultation of heart sounds

On keeping one's ears to the chest wall of another person, it is possible to hear some sounds. On keen observation, these sounds can be correlated with the functioning of the heart. The same sounds are heard better with a stethoscope.

Normally, two sounds are heard: the familiar ***lub-dup***. The first ***'lub'*** sound is due to contraction of the ventricles during systole and the consequential closing of the tricuspid and mitral valves. The second ***'dup'*** sound is due to the sharp closure of the pulmonary and aortic valves.

Though there are only two sounds, the same can be heard with differing emphasis at four different areas on the anterior chest wall (corresponding to the four valves). It is essential to know these areas so as to be able to hear the heart sounds with care and arrive at a diagnosis.

contd...

Clinical Correlation *contd...*

- ***Tricuspid valve:*** Best heard over the right half of the lower part of sternum;
- ***Mitral valve:*** Best heard over the apex, i.e., at the level of the fifth left intercostal space about 9 cm from the midline;
- ***Pulmonary valve:*** Best heard over the medial end of the second left intercostal space;
- ***Aortic valve:*** Best heard over the medial end of the second right intercostal space.

Valvular Disease of the Heart

All the four valves (tricuspid, mitral, pulmonary and aortic) are prone to damage. The commonest cause for valvular damage is rheumatic disease. Inflammation of the valve in the early stages of the disease causes the edges of the cusps to become sticky and attached to each other. In due course, fibrous thickening occurs. The cusps shrink and lose their flexibility. The valve thus becomes mutilated in shape and loses its function. Either narrowing of the valvular flow area (called ***stenosis***) or valvular incompetence (valve not able to prevent back flow thus leading to regurgitation) or both can occur. Other related tissues may also be involved. The ***chordal tendineal*** shorten and prevent closure of the cusps during systole adding to the regurgitation. Any of the four valves can go in for stenosis or regurgitation; combination of these defects may occur. The heart ceases to function as an efficient and effective pump.

- ***Heart murmurs***: Normally, apart from the lub-dup sounds, passage of blood through the heart is silent. In cases of valvular disease with stenosis or regurgitation, narrowing, distortion and back flow cause turbulence and vibrations in blood flow. These vibrations are heard as additional abnormal sounds and are called ***murmurs***. Each of the condition has a distinct murmur and many of the valvular defects can be diagnosed by listening carefully to the heart sounds and murmurs.
- ***Mitral Valve Disease:*** As a result of infection and of subsequent fibrosis, the cusps become thickened with reduced mobility; they often fuse with each other. This leads to a narrowed mitral orifice resulting in ***mitral stenosis***. Blood flow from left atrium to left ventricle is reduced and necessitates greater force. Mitral stenosis is often combined with regurgitation (some blood flowing back from ventricle to atrium). All this adds greatly to load on the left atrium leading to its dilatation. Back pressure leads to pulmonary hypertension. In an effort to push blood through the pulmonary circulation (which is now at a higher pressure and offers resistance to blood flow), the right side of the heart has to work harder and eventually there is right heart failure. Surgical correction of mitral stenosis is one of the most common surgical operations on the heart. In earlier days, closed mitral valvulotomy was performed. At present times and with the advent of the heart-lung machine, open heart procedures have gained importance. Repair of the valve is done. If the diseased valve is beyond repair, it is replaced with a synthetic or a xenografted (transplanted from other animals) valve. The procedure is called ***mitral valvuloplasty or valve replacement***.

  A ***floppy mitral valve*** is a common condition, often with no symptoms. The cusps are large, redundant and floppy**.** With an associated mitral regurgitation, the cusps extend into the left atrium during systole. A characteristic murmur is produced by the reversed blood flow into the atrium. In a small section of people, the condition is symptomatic and needs treatment.

contd...

Clinical Correlation *contd...*

- ***Tricuspid valve disease:*** The tricuspid valve can also be similarly affected. However, back stagnation causes load on the right atrium and venous return. This gives an appearance of right heart failure and related symptoms are seen early. Repair and replacement surgical procedures are done to provide relief to affected patients.
- ***Pulmonary and aortic valvular disease:*** These orifices may become too narrow (stenosis) or may show regurgitation. The defects can be corrected by surgery. Such cases have also been treated by a technique in which a cardiac catheter with a balloon is passed into the region and the valve dilated; the procedure is called ***percutaneous balloon valvulotomy***.
- ***Acquired aortic valve disease:*** As a consequence of endocarditis, the aortic valve may undergo stenosis, or may show regurgitation. In either case, the load on the left ventricle is greatly increased and in untreated cases, this can lead to left heart failure. The favoured surgical treatment is valve replacement.

Added Information

- The thickness of the walls of the ventricles is proportional to the work they do. Before birth, both ventricles pump blood into the aorta, the left directly and the right through the ductus arteriosus. So the pressure is the same and the load on each ventricle is the same; the walls are also equal in thickness. After birth, the left ventricle has to pump with more force and so the walls of the left ventricle increase in thickness. The ratio of thickness is 3:1 (left: right).
- Developmental rotation of the heart to the left causes one third of the left and two thirds of the right ventricles to face anteriorly and two thirds of the left and one third of the right ventricles to face posteriorly.
- In olden times, the moderator band was supposed to prevent over distension of the right ventricle, i.e., moderate the right ventricle. Hence, the name.
- In reality, the moderator band transmits the right branch of the atrioventricular bundle to the anterior papillary muscle. It is now named by its location—septum to anterior wall—and called the ***septomarginal band***. The band may be absent. In such cases, the anterior papillary muscle arises at the junction of the anterior and septal walls. The conduction branch directly reaches the muscle within the ventricular wall itself and there is no necessity for the band to separate itself and run through the cavity.

CONDUCTING SYSTEM OF THE HEART (FIG. 7.23)

The normal heart contracts rhythmically at a rate of about 70 to 90 beats per minute. This rate may vary depending upon the age of the individual and the kind of work/activity the individual is performing at the specified time. Diseases may also cause variations in this rate.

The rhythmic process of contraction and its occurrence in the various chambers at slightly altered intervals are controlled by the conduction system of the heart. This system is also responsible for the spontaneous origin of the rhythm. The conduction system ensures that the atria contract first and are followed by the ventricles. The delay

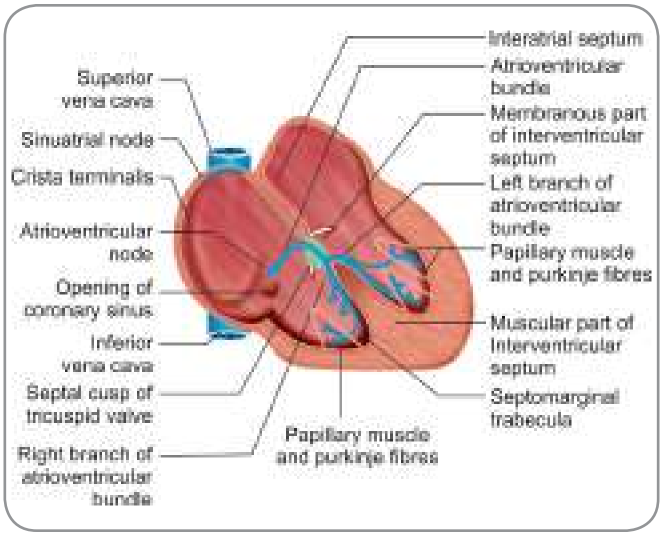


Fig. 7.23: Schematic view of the interior of the heart to show the parts of the conducting system

between atrial and ventricular contraction ensures the atria contract and fill the ventricles before the latter contract. Thus the conduction system has an area of origin of the contraction impulse and other areas which are responsible for the transmission of this impulse to different parts of the heart. The sinoatrial node, the atrioventricular node, the atrioventricular bundle, the branches of the bundle and the Purkinje fibres constitute the conduction system.

- ***Sinoatrial node (SA node):*** This is a small area in the wall of the right atrium along the anterior margin of the opening of the superior vena cava. The greater part of the node lies in the sinus venarum part of the atrium, but anteriorly it extends into the crista terminalis. The node gives rise to spontaneous electrical impulses which spread throughout the atrial musculature of both sides causing it to contract.
- ***Atrioventricular node (AV node):*** This is situated in the lower part of the interatrial septum just above the attachment of the septal cusp of the tricuspid valve and the opening of the coronary sinus. Some of the impulses generated in the SA node, as they pass through the atrial musculature, reach the AV node.
- ***Atrioventricular bundle (AV bundle or Bundle of His):*** Arising from the AV node, this bundle passes forwards in the interatrial septum, between the right side of the septum and the septal cusp of the tricuspid valve, to reach the membranous part of the interventricular septum. It descends to the upper rim of the muscular septum and at this level divides into right and left branches. The bundle is the only pathway through which the atrial musculature and the ventricular musculature are connected and the only route through which impulses from atria reach the ventricles.
- ***Branches of the bundle:*** The right bundle branch (or the right crus) runs downwards and forwards on the right side of the muscular part of the interventricular septum, towards the apex of the heart. It passes through the septomarginal trabecula to reach the base of the anterior papillary muscle. The left bundle branch (or the left crus) pierces the septum, descends on its left side beneath the endocardium and divides into anterior and posterior branches.
- ***Purkinje fibres:*** Otherwise called the ***conduction myofibres***, these fibres of the conduction system form a dense network deep to the endocardium of the ventricular chambers. The branches of the bundle, at the bases of the papillary muscles divide into smaller branches which continue into the ***Purkinje plexus***. The entire musculature of both the ventricles are ramified by the Purkinje network.

The SA node, the AV node, the atrioventricular bundle and its branches and the Purkinje fibres are all made up of specialised tissue that has a partial resemblance to the structure of cardiac muscle. This tissue conducts impulses faster than cardiac muscle but slower than regular nerve fibres. Impulses arising in the SA node and spreading into the atrial musculature cause the atria to contract. These impulses reach the AV node, pass through the AV bundle and its branches to reach the ventricular muscle. Conduction through the AV node, AV bundle, bundle branches and Purkinje fibres takes time. As a result, the contraction of the ventricles is not simultaneous with that of the atria, but follows after a definite interval. Within the ventricles themselves, the papillary muscles are the first to contract (as the branches of the AV bundle reach here first). This ensures closure of the mitral and tricuspid valves before the ventricles contract.

Added Information

- The conduction system is influenced by the autonomic innervation of the heart. Sympathetic stimulation causes increase of the rate and the speed of conduction. Parasympathetic stimulation causes slowing of the rhythm and reduces the speed of contraction.
- The SA node is a crescentic mass of specialised cardiac muscle cells. It generates 70 to 80 impulses per minute. It, therefore, is the pacemaker of the heart.
- The conducting system has specialised cardiac muscle cells. The cells of the SA and AV nodes and the AV bundle, on external appearance, are typical cardiac muscle cells but smaller in size and with functional specialisation. The Purkinje fibres are made up of large barrel shaped cardiac muscle cells which line up in long rows. As they are specialised for conduction and not contraction, they have few myofilaments. The large size of the Purkinje fibres helps in rapid conduction of the impulse.
- Though the transmission of impulses from the SA node through the atrial musculature is by the gap junctions of the

contd...

Added Information ***contd...***

atrial cardiac muscle cells, there is no direct spread to the ventricular walls. The route is only through the AV node and AV bundle.

- ***Presence of internodal pathways:*** Impulses from SA node travel to the AV node. This travel appears to be faster than the transmission of the same impulses through atrial musculature. If two simultaneous impulse waves are studied within a time frame, it can be seen that the wave passing through the internodal route takes a shorter time than its counterpart through the atrial musculature for the specified distance. This has made some workers explain the presence specialised internodal pathways. Three such pathways have been described. All of them are within the right atrial wall.
  - ***The anterior internodal pathway:*** It starts at the anterior end of the SA node and extends to the AV node anterior to the superior venacaval opening;
  - ***The posterior internodal pathway:*** It starts at the posterior end of the SA node and extends to the AV node through the crista terminalis and the valve of the inferior venacaval opening;
  - ***The middle internodal pathway:*** it starts at the posterior end of the SA node and extends to the AV node posterior to the superior venacaval opening.

  The presence of special internodal tracts are of course disputed by many; dense arrangement and packing of normal atrial musculature is supposed to cause faster transmission.
- As the bundle branches break into a network of Purkinje fibres, the fibres first approach the apex of the heart and then turn superiorly into the ventricular walls to ultimately reach the subendocardial area. This arrangement is important. The impulse travels from the SA node to the Purkinje fibres and then reach the ventricular wall myocardium at the level of the apex. So, contraction starts from the apex and proceeds upwards . The outflow tracts of both the ventricles are on the superior aspects of the chambers and this pattern of contraction ensures that there is smooth outflow and residual stasis is prevented.

Clinical Correlation

- The AV bundle may fail to transmit the impulses properly. In such a case, alteration in the rhythmic contraction of the ventricles occurs. This results in arrhythmias. Sometimes, complete block may also occur leading to total dissociation in the contractions between the atria and the ventricles. Partial or complete blocks may also occur in one of the bundle branches causing bundle branch blocks. The commonest cause for such blocks is atherosclerotic narrowing of the coronary arteries reducing blood supply to some part of the conducting system.
- Artificial cardiac pacemakers can be fixed in patients with heart block. The pacemaker has a pulse generator that produces electrical impulses at a predetermined rate. An electrode connected to the pulse generator is made to reach the right ventricle where it is fixed to the trabeculae carneae in contact with the endocardium.

FIBROUS SKELETON OF THE HEART (FIG. 7.24)

The fibrous skeleton is a framework of dense collagen with membranous, tendinuous and fibroareolar extensions. This framework is located at the ventricular base and is related to the atrioventricular valves and the aortic orifice. The main part of the framework is the central fibrous body. Two pairs of curved collagenous prongs project from the central fibrous body. These are the fila coronaria. One pair of fila coronaria surround the mitral and tricuspid orifices. Extensions of the central fibrous body also surround the aortic orifice; this aortic framework is anterosuperior and to the right of the mitral orifice. Two of the cusps of the aortic valve are in continuity with the aortic cusp of the mitral valve. This curtain of collagen is called the sub-aortic or the aoryic-mitral curtain. This curtain is also a part of the fibrous skeleton. The two ends of the curtain are thicker than the other portions and are stronger. These also form the strongest portion of the fibrous skeleton and are called the right and left fibrous trigones. The left fibrous trigone is at the aortic-mitral junction. The right fibrous trigone is at the tricuspido-mitral junction. The membranous septum of the interventricular area forms an integral part of the fibrous skeleton. The right fibrous trigone and the membranous septum together constitute the central fibrous body. The central fibrous body is penetrated by the bundle of His and is supposed to play a significant role in cardiac impulse conduction.

Though the two pairs of fila coronaria appear prominent, the central structure of the fibrous skeleton is the aortic root skeleton, which is often described as the annulus of the skeleton. The structure of the aortic root skeleton is

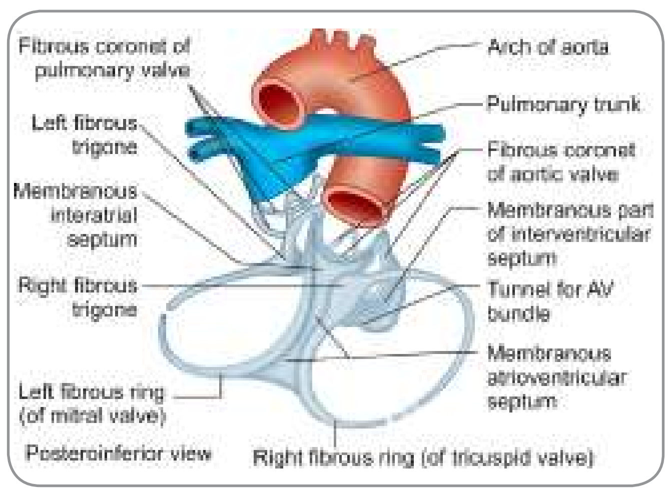


Fig. 7.24: Fibrous skeleton of heart—A simplified definition for the fibrous skeleton can be drawn from this figure that shows the skeleton in isolation; the skeleton consists of two rings encircling the aortic and pulmonary valves, two coronets (coronarial rings) encircling the mitral and tricuspid valves, two trigones which are the right and left trigones and the membranous portions of the interatrial, interventricular and atrioventricular septa

in conformity with the triple semilunar attachments of the three aortic cusps. There are three triangles described within this aortic complex. Known as the subaortic spans, the three triangles have their apices towards valvular commissures. The first fibrous triangle is between the non-coronary and the left coronary sinuses of the aortic vestibule and is filled with the subaortic curtain. The second triangle is between the non-coronary and the right coronary sinus and is continuous with the membranous septum. The third triangle is between the two coronary aortic sinuses and is filled with fibroelastic tissue. This tissue separates the subaortic root from the subpulmonary infundibulum. This is the location of the conus ligament.

The pulmonary orifice is often stated to be contained within the skeleton. However, this is not completely true. The pulmonary cusps stand on the sleeve of right ventricular infundibulum and can be separated off without disturbing the fibrous skeleton.

The functions of the fibrous skeleton are two: a. it forms a stable but deformable base for the attachments of the fibrous cores of the atrioventricular valves; b. it ensures electrophysiological discontinuity between the atrial and ventricular myocardial masses (except in the area of penetration of the conduction tissue).

BLOOD SUPPLY OF HEART

Arterial Supply

The arterial supply to the heart is provided by the coronary arteries which are branches of the ascending aorta. The coronary arteries and their branches lie within the subepicardial connective tissue and are distributed on the surface of the heart (Fig. 7.25).

Right Coronary Artery (RCA)

The right coronary artery arises from the anterior aortic sinus of the ascending aorta. It runs anteriorly between the right auricle and the pulmonary trunk. Reaching the anterior atrioventricular groove, it then descends down the groove. At the inferior border of the heart, it winds around the border and runs up in the posterior atrioventricular groove. On the posterior aspect, its terminal branches anastomose with the terminal branches of the anterior interventricular artery. The right coronary artery supplies the right atrium, most of right ventricle and small parts of left atrium and ventricle. Throughout its course, it gives out branches which in turn supply different parts of the heart.

- ***The right conus artery:*** It supplies the infundibulum (otherwise called the pulmonary conus) of the right ventricle and the adjoining part of the anterior wall of right ventricle.
- ***The atrial branches:*** These are many in number and supply the anterior and lateral parts of the right atrium. One or two branches supply the posterior aspects of the right and the left atria. A separate branch called the artery of the sinoatrial node supplies the (sinoatrial node) and parts of both atria. This branch is usually given out near the origin of the RCA itself.
- ***The anterior ventricular branches:*** These are two or three in number and supply the anterior part of the right ventricle. One of them is given out along the inferior margin of the heart and is called the marginal artery. Running along the margin, the marginal artery stops short of the apex.
- ***The posterior ventricular branches:*** These are two or three in number and supply the inferior part of the right ventricle.
- ***The posterior interventricular artery:*** They are otherwise called the posterior descending artery, it is given out on posterior aspect and descends along

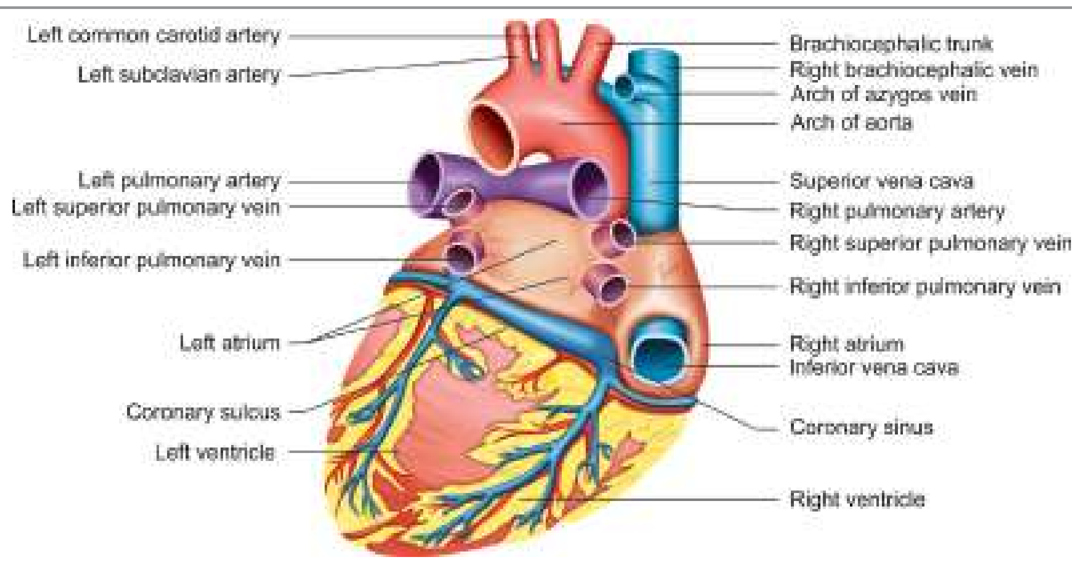


Fig. 7.25: Inferior and basal aspects of heart to show major vessels

the posterior interventricular groove. As it runs down the groove, it gives branches to both ventricles and to the upper part of the interventricular septum. One of the septal branches is large and usually supplies the atrioventricular node. This nodal branch is usually given out at the crux of the heart.

Left Coronary Artery

The left coronary artery arises from the left posterior sinus of the ascending aorta and runs forwards between the pulmonary trunk and the left auricle. Reaching the atrioventricular groove, it almost immediately divides into an anterior interventicular branch and a circumflex branch. The left coronary artery is larger than the right coronary artery and supplies the greater parts of left atrium and ventricle and a large portion of the interventricular septum including its apical area.

- ***The anterior interventricular artery:*** They are otherwise called the anterior descending artery or the left anterior descending artery, it runs down the anterior interventricular groove to the apex of the heart. It winds around the apex and enters the posterior interventricular groove. Ascending up the posterior groove, it branches into its terminal branches which anastomose with the terminal branches of the right coronary artery. As it runs in the anterior interventricular groove, it gives out several ventricular branches which supply the right and left ventricles and the anterior part of the interventricular septum. One of the ventricular branches may be large and run diagonally across the anterior surface to warrant a name 'the diagonal artery'. The apical part of the septum in toto is supplied by its branches. It also gives out a small left conus artery that supplies the pulmonary conus.
- ***The circumflex artery:*** This artery continues from the parent trunk along the atrioventricular groove and winds around the left margin of the heart to reach the posterior part of the same groove. It gives out a left marginal artery as it winds around the left margin; this branch runs along the left margin of the heart (the left margin of the left ventricle) till the apex and supplies the left ventricle. Many anterior and posterior ventricular branches are also given out and these supply the different parts of the left ventricle. Atrial branches from the circumflex artery supply the left atrium.

Summary of Coronary Distribution

- ***Right Coronary artery:***
  - Right atium
  - Part of left atrium
  - Most of right ventricle (except a small part on the right of anterior interventricular groove)
  - Some part of the diaphragmatic surface of left ventricle
  - Posterior third of the interventricular septum
  - Sinoatrial node, atrioventricular node, atrioventricular bundle and some part of left bundle branch

Added Information

Tendon of todaro: Anterior to the opening of the inferior vena cava is a flap like valve called the Eustachian valve or valve of inferior vena cava. The opening of the coronary sinus has a thin, semilunar valve that guards the lower part of the orifice; this is the Thebesian valve. The upper limb of the Thebesian valve joins the Eustachian valve. A tendinous structure called the tendon of Todaro runs from this point of commissure to the sinus septum. The sinus septum is the septum between the coronary sinus and the fossa ovale. The tendon of Todaro runs forwards into the central fibrous body and forms a landmark for the triangle of Koch.

Triangle of koch: This is a triangle, the boundaries of which form the anatomical landmarks for the atriventricular node. The boundaries of the triangle are: superiorly – tendon of Todaro, inferiorly – attachment of septal cusp of tricuspid valve and basally – orifice of coronary sinus. The atrioventricular node lies at the apex of this triangle.

- ***Left Coronary artery:***
  - Most of left atrium
  - Most of left ventricle
  - Small part of right ventricle to the right of the anterior interventricular groove
  - Anterior two thirds of interventricular septum and some parts of the AV bundle
  - Right and left bundle branches

Arterial Supply to the Conduction System

The sinoatrial node, the atrioventricular node and the atrioventricular bundle are supplied by the right coronary artery. The right bundle branch of the AV bundle is supplied by the left coronary artery. The left bundle branch derives blood from both the arteries. The sinoatrial node may sometimes be supplied by the left coronary artery.

Coronary Dominance

Variations in the branches of the coronary arteries do occur. The origin, size and distribution of the posterior interventricular artery decides the status of coronary dominance. In right dominance (typical and commoner), this artery arises from the right coronary artery. In left dominance, it arises from the circumflex branch of the left coronary artery. In 65% of the population, it is right dominance and in 35% it is left dominance.

Coronary Anastomoses

There appears to be a wide anastomosis between the terminal branches of the right and the left coronary arteries. However, though these connections exist anatomically, their functional existence is questionable. In other words, if a larger branch of one of the coronary arteries is blocked and that part of the cardiac muscle supplied by the blocked vessel is in trouble, the collateral circulation is inadequate (functional end arteries) to supply sufficient blood to the troubled muscle. Therefore, a sudden block of one of the larger vessels causes ischaemia and subsequent infarction (myocardial infarction) leading to death.

Venous Drainage

The veins of the heart predominantly drain into the coronary sinus. Some of the drainage is through the small veins which open directly into the right atrium.

The coronary sinus is the main vein of the heart. It is a wide venous channel that runs from left to right in the posterior aspect of the coronary sulcus. Lying across the posterior aspect of the heart, it receives the great cardiac vein at its left end and the small and middle cardiac veins at its right end. Oblique vein of left atrium, left marginal vein and left posterior ventricular vein are its other major tributaries. The coronary sinus, at its right end opens into the right atrium.

Of the tributaries of the coronary sinus, the great cardiac vein is the largest. It starts as the anterior interventricular vein near the apex and ascends up the anterior interventricular groove lying alongside the anterior interventricular branch of the left coronary artery. On reaching the coronary sulcus, it turns left and continues as the great cardiac vein to wind around the left margin of the heart and subsequently join the coronary sinus. Throughout its way, it receives several unnamed tributaries and drains the areas of the heart which are supplied by the left coronary artery.

The middle cardiac vein (otherwise called the posterior interventricular vein) starts near the apex but on the posterior aspect. It ascends up the posterior interventricular groove along with the posterior interventricular artery. The small cardiac vein is formed at the inferior border of the heart and runs up alongside the right marginal artery. Both the middle and the small cardiac veins open into the coronary sinus. Together these two veins drain the areas supplied by the right coronary artery.

The oblique vein of left atrium (also called the oblique vein of Marshall) is a small vein descending on the posterior wall of the left atrium; it joins with the great cardiac vein to form the coronary sinus. Thus the commencement of the coronary sinus can be determined by the point of joining of the oblique vein.

Several anterior cardiac veins start over the anterior surface of the right ventricle. They cross the coronary sulcus, reach the right atrial anterior surface and directly open into its chamber. A few of them, which are close to the inferior border, may open into the small cardiac vein. The venae cordis minimae or the smallest cardiac veins are tiny vessels which begin in the myocardium and end directly into the chambers of the heart, predominantly in the atria.

Added Information

- The oblique vein of Marshall is a non-descript vein postnatally. It is the remnant of the embryonic left superior vena cava. It usually dwindles and atrophies during development. Only a small portion remains and joins the coronary sinus. In some, it may persist and aid the right SVC or replace the latter.
- The venae cordis minimae, though called veins, are actually channels of valveless communication. They run between the myocardial capillary plexus and the heart chambers. They are capable of carrying blood both ways and may serve as important channels in extreme situations.

Clinical Correlation

- ***Ischaemic Heart Disease***
  - With increasing age, all arteries of the body undergo atherosclerosis. As a result of this, their lumina become narrower. This process also takes place in the coronary arteries reducing oxygen supply to the myocardium. Narrowing of coronary arteries produces no symptoms as long as enough oxygen is available to meet the requirements of the person.
  - At a later stage, oxygen supply becomes insufficient at certain levels of activity (like exercise or climbing stairs, because the demand for oxygen in such circumstances is more and the heart has to pump faster and more) and insufficient oxygen supply then leads to severe pain and a sense of constriction in the chest. This is the stage of ***angina pectoris***. Angina pectoris (Latin.angino=choking/strangling; pector /pectis=chest) is a constricting pain in the chest usually caused by a temporary deficiency in the delivery of blood to the myocardium. It results from stress-induced spasms of the coronary arteries or narrowing due to atherosclerosis. The pain is predominantly in the region of the sternum. It can radiate to the left shoulder and arm, into the neck and jaw, or to the back. It can also radiate in other directions. Spasms can be relieved by appropriate drugs that can, therefore, relieve and prevent the occurrence of angina.
  - Complete blockage of a branch of a coronary artery leads to death of the part of the myocardium supplied by that branch. This is ***myocardial infarction*** (Latin.infarctio=stuffed into; so named because the arteries appear stuffed due to atherosclerosis). Myocardial infarction (or heart attack in layman's language) can result in death.
- ***Detailed anatomy of anginal pain and 'heart attacks':*** Strenuous physical activity, exercise, sudden exposure to cold and stressful situations require increased blood flow to certain parts of the body and thus place a greater demand on the heart. But the 'blocked' vessels are not able to meet with the demand. The myocardium is deprived of oxygen. Anaerobic metabolism takes place in the myocardium resulting in lactic acid accumulation. This lactic acid stimulates the pain receptors.
- ***Coronary bypass grafting:*** This is a procedure carried out for patients with coronary arterial blocks. A graft (that is, a piece of artery or vein) is connected from the portion of the coronary vessel proximal to the block to the portion distal to the block. A bypass route to the block is thus created by a graft vessel. The great saphenous vein, internal thoracic artery or radial artery of the patient will be used as the graft. The great saphenous vein is usually the preferred graft vessel because (a) it has almost the same diameter

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Clinical Correlation *contd...*

as the coronary vessel, (b) it is easy to harvest the vein and (c) sufficient length (without or with minimal valves) can be harvested. The grafted segment is reversed so that no hindrance to blood flow occurs even if there is a valved piece.

- ***Cardiac Arrest:*** This term is used to describe stoppage of the beating of the heart. Cardiac arrest may result from a wide range of causes. A patient with cardiac arrest can be saved if immediate resuscitative measures are taken. Mouth to mouth breathing, and external cardiac massage are relatively simple procedures which can be learnt even by a lay person and can save the life of a person in cardiac arrest if used immediately and appropriately. In some cases in whom, closed chest cardiac massage does not succeed in restarting the heart, an ***open cardiac massage*** can be done by opening the thorax.
- ***Cardiopulmonary resuscitation and its anatomy:*** Compression of the chest or external cardiac massage is the usual method of cardiopulmonary resuscitation. Two mechanisms take place. The heart is compressed between the sternum and the vertebral column leading to mechanical stimulation of the heart and flow of blood in and out of the heart due to the alternate compression and release of compression. The second mechanism is where the entire thoracic cage acts as pump. With every compression, due to increased intrathoracic pressure, blood is forced out through the arteries. With every release of compression, the intrathoracic pressure falls and blood enters into the thoracic cage through the venous system. With more compressions, the external pressure gradient includes the heart and the heart starts beating gradually.

LYMPHATIC DRAINAGE OF HEART

Lymphatics from the subendocardial connective tissue and the myocardium reach the subepicardial lymphatic plexus. Lymphatic vessels which arise from this plexus reach the coronary sulcus and run alongside the coronary arteries. They crisscross and unite. One large vessel thus formed (sometimes two or three) ascends between the left atrium and the pulmonary trunk to end in the inferior tracheobronchial lymph nodes.

NERVE SUPPLY OF HEART

Nerve supply to the heart can be subdivided into (1) autonomic innervation and (2) sensory innervations.

- The ***autonomic innervation*** of the heart is through the cardiac plexuses which are situated below the arch of aorta. The plexuses receive postganglionic sympathetic fibres from the cervical and superior thoracic parts of the sympathetic trunk and postganglionic parasympathetic fibres from the vagus nerves.

  The sympathetic fibres reach the sinoatrial and atrioventricular nodes, the cardiac muscle fibres and the coronary arteries. Sympathetic stimulation causes increased rate of cardiac contraction, increased force of contraction and dilatation of the coronary arteries. The parasympathetic fibres end in the sinoatrial and atrioventricular nodes and the coronary arteries. Parasympathetic stimulation decreases cardiac rate, reduces force of contraction and causes constriction of the coronary arteries.
- Afferents from the heart travel along the sympathetic fibres; they do not reach levels of consciousness. However, when the myocardium is deprived of blood supply, pain impulses do reach consciousness through this path. Those afferents which travel along the parasympathetic pathway take part in cardiac reflexes.

The control centres for the autonomic impulses to the heart are in the medulla. The cardioacceleratory centre influences the sympathetic impulses and the cardio inhibitory centre influences the parasympathetic impulses.

SURFACE PROJECTION OF HEART (FIG. 7.26)

The heart is an extremely important organ. It is necessary to project different parts of the heart to the surface (chest wall) in order to either learn or examine details of its functioning.

Anterior projection: The borders of the heart can be projected on to anterior chest wall. For this projection, the heart can be described to have a superior border, an inferior border, a right border and a left border. In addition, it has an apex.

- ***Superior border:*** Point A is marked on the upper border of the third right costal cartilage about 1 cm from the sternal margin. Point B is marked on the lower border of the second left costal cartilage about 1 cm from the sternal margin. These two points are joined by a straight line. It will be seen that this line slopes upwards from right to left.
- ***Inferior border:*** Point C is marked on the sixth right costal cartilage about 1 cm from the sternal margin. Point D is marked on the fifth left intercostal space immediately medial to the midclavicular line. These two points are joined by a line which is slightly convex downwards at its right and left ends and slightly concave downwards in the middle.
- ***Right border:*** This border extends from the third right costal cartilage to the sixth right costal cartilage. Thus Point A (the right end of the superior border) and point C (the right end of the inferior border) are connected by a line which is convex, the maximum convexity being in the fourth intercostal space.
- ***Left border:*** This border extends from the second left costal cartilage to the apex beat of the heart. Thus Point

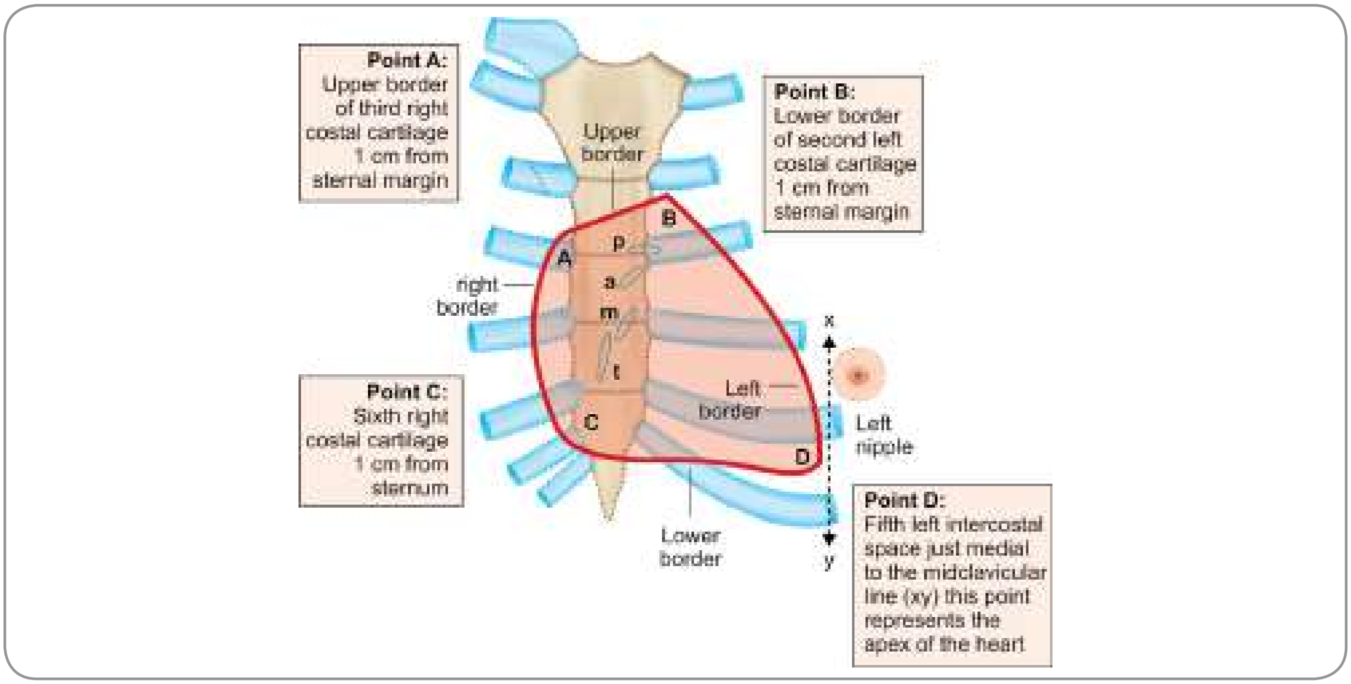
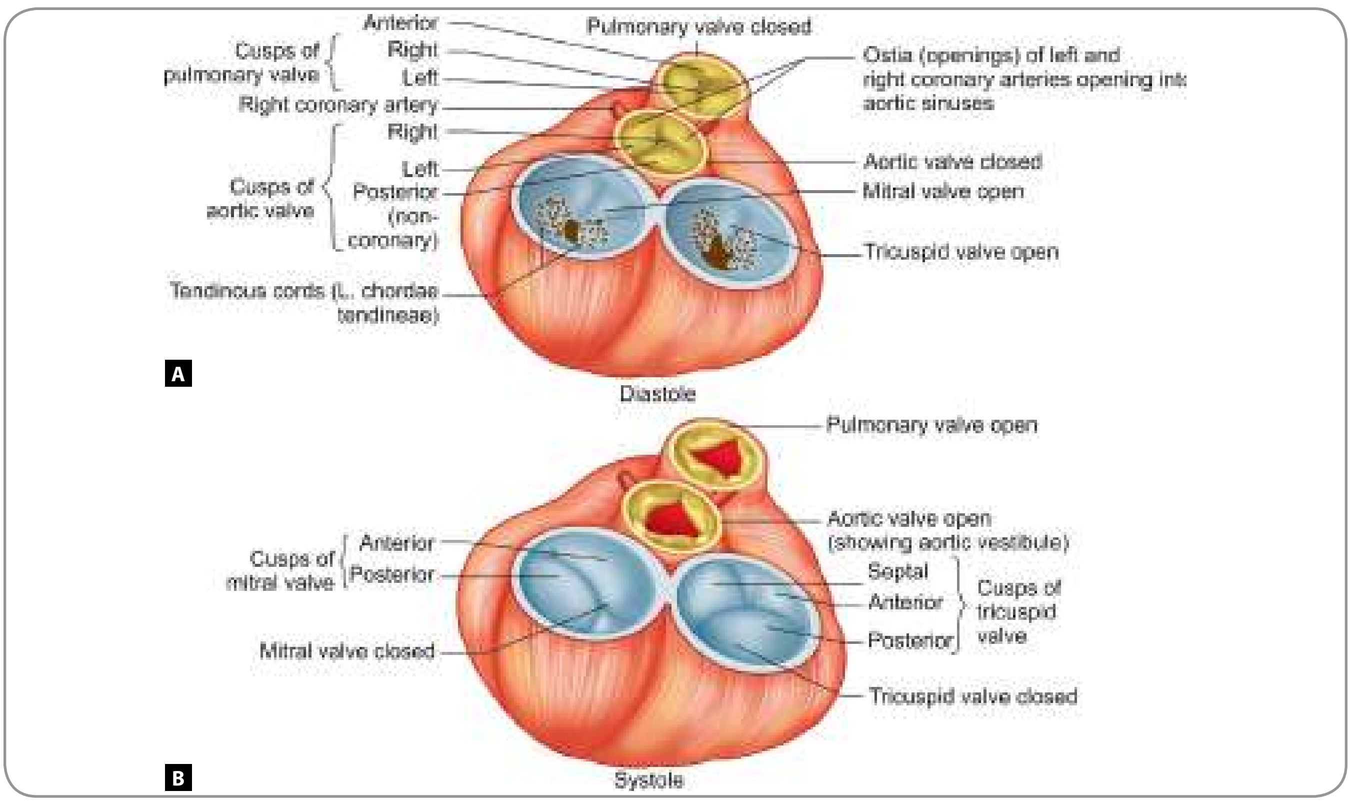


Fig. 7.26: Surface projection of the heart
Key: p. Pulmonary valve **a.** Aortic valve **m.** Mitral valve **t.** Tricuspid valve

B (the left end of the superior border) and point D (the left end of the inferior border) are connected by a line which is convex to the left.

Apex of the heart (Fig. 7.27A and B): This is marked on the fifth left intercostal space immediately medial to the midclavicular line.



Figs 7.27A and B: Scheme to show the valves of the heart (posterior view)

Valves of the heart (Fig. 7.27): All the four important valves can also be projected on the surface, on a line connecting points B and C mentioned above.

- The ***pulmonary valve*** is about 2.5 cm broad and lies partly behind the left third costal cartilage, and is partly behind the sternum.
- The ***aortic valve*** is about 2.5 cm broad. It is placed obliquely behind the left half of the sternum at the level of the third intercostal space.
- The ***mitral valve*** is about 3 cm wide. It is placed obliquely deep to the left half of the sternum at the level of the fourth costal cartilage.
- The ***tricuspid valve*** is about 4 cm broad. It is placed almost vertically behind the sternum. Its upper end lies in the midline at the level of the fourth costal cartilage. Its lower part inclines slightly to the right and reaches the level of the fifth costal cartilage.

Clinical Correlation

Investigative Procedures: Several procedures are utilised in order to investigate the functioning of the heart.

- ***Plain X-rays of the chest:*** A radiograph of the chest can give useful information about some parts of the heart or great vessels. In a plain skiagram of the chest, the heart and other structures produce a shadow in which several individual prominences can be recognised. Along the left border of the shadow, prominences (from above downwards) seen are:
  - The aortic arch
  - The pulmonary artery
  - The left auricle
  - The left ventricle

  Along the right border of the shadow, these are (from above downwards):
  - The superior vena cava
  - The right atrium

  The inferior border of the shadow is formed mainly by the right ventricle. Enlargement of any of these structures can produce alterations in the appropriate part of the heart shadow. The heart shadow in a radiograph can be studied with reference to the costal cartilages and ribs and the dimensions of the sternocostal surface made out. If the shadow exceeds the normal limits, it can be deduced that the heart is enlarged (cardiomegaly).
- ***Cardiac Catheterisation and Angiography***
  - A fine catheter introduced into the brachial or femoral artery can be made to pass into the left side of the heart. Similarly, a catheter introduced into the femoral vein can reach the right side of the heart. The procedure is done under X-ray control. Cardiac catheterization is used to collect samples of blood from individual chambers for analysis. Pressures within the chambers can also be recorded. Dyes can be injected into specific parts to obtain angiograms.
  - Visualisation of the coronary vessels and their branches is possible by injecting contrast dye into them. This procedure is called ***coronary angiography*** and the picture thus obtained is coronary angiogram. Sites of narrowing of the vessels can be determined.
  - Catheterisation can be used for certain sophisticated interventional procedures.
- ***Coronary angioplasty and stenting:*** Percutaneous transluminal coronary angioplasty is a procedure done for relieving coronary obstructions. A catheter with a small balloon attached to its tip is inserted. This is passed into the obstructed coronary artery and once it reaches the site of obstruction, the balloon is inflated. The atherosclerotic plaque that obstructs the vessel is flattened and patency of the vessel restored. Drugs like thrombokinase can be injected at the site to dissolve the thrombotic clot. To maintain the dilatation, intravascular stents may be introduced.
  - ***Echocardiography:*** Otherwise called ultrasonic cardiography, this technique records the position and movements of the heart by echoes obtained from ultrasonic waves sent in. Even very small lesions and collection of very little pericardial fluid can be detected by this method. Doppler echocardiography records blood flow through the various chambers and vessels. Apart from the volume of flow, velocities can also be measured.

Added Information

- The atrioventricular groove of the heart is otherwise called the ***coronary sulcus*** since it circles the junction between the atria and the ventricles like a crown (Latin.corona=crown). All structures present in the coronary sulcus are also given the name ***'coronary'***. The large venous sinus in the posterior part of the coronary sulcus goes by the term ***'coronary sinus'*** and the two arteries arising from the ascending aorta and running in the coronary sulcus are called the ***coronary arteries***. These arteries also surround the heart like a crown.
- The papillary muscles do not function to open the atrioventricular valves. When the ventricles contract during systole, the papillary muscles also contract. Meanwhile, the intraventricular pressure rises and blood is forced upwards against the atrioventricular valvular cusps. The cusps close and thus the AV valves also close. The chordal tendineal and the papillary muscles which are attached to the cusps keep the cusps anchored in their closed position, serving as guy ropes. If this anchorage were not to happen, the cusps would be blown into the atria in the force of the blood flow. Thus the action of the papillary muscles is to anchor the atrioventricular valves and prevent their eversion.

contd...

Added Information *contd...*

- While listening to the heart sounds with a stethoscope, one does not listen directly over the valves. The respective sounds take oblique routes through the heart chambers and reach the chest wall. Each valve is best heard at a particular reference point.
- The ***'best heard'*** points of the heart valves can be easily linked to the 'four corners' of the heart. When the surface projection of the heart is made on the anterior chest wall, there are four corners to this projection and each valve is best heard in one corner. The aortic valve is best heard at the right superior corner, the pulmonary valve at the left superior corner, the tricuspid valve at the right inferior corner and the mitral valve at the left inferior corner.

Multiple Choice Questions

1. The oblique sinus of pericardium:
   a. Is the recess trapped by the pericardium around the great veins
   b. Lies behind the parietal serous pericardium
   c. Does not communicate with the rest of the pericardial cavity
   d. Does not provide buffer action like the transverse sinus

2. The wall of the fossa ovalis in an adult right atrium represents the:
   a. Septum secundum
   b. Septum primum
   c. Septum spurium
   d. Conus septum

3. The moderator band of the right ventricle stretches from the:
   a. Anterior wall to the septal wall
   b. Posterior wall to the septal wall
   c. Anterior wall to the posterior wall
   d. Lower part of anterior wall to the upper part

4. The chordal tendineal of the anterior cusp of the mitral valve attach to:
   a. The ventricular surface of the cusp
   b. The atrial surface of the cusp
   c. The margin of the cusp
   d. Both ventricular and atrial surfaces of the cusp

5. The right bundle branch of the AV bundle derives blood supply from:
   a. The right coronary artery
   b. The left coronary artery
   c. Both the coronary arteries
   d. Any one of the coronary arteries (variably)

ANSWERS

1. a **2.** b **3.** a **4.** c **5.** b

Clinical Problem-solving

Case Study 1: A 68-year-old man appears in the clinical examination stating that he has angina for the last four years.
- What is your understanding of the condition?
- Where all can the pain of angina present?
- What is the relationship between angina and myocardial infarction?

Case Study 2: In your clinical postings, you are asked to explain about the sounds of the heart valves. Take a trial now.
- While listening with a stethoscope, how many of the heart valves are directly heard over (that is stethoscope directly placed over the valves) and what are they?
- Where are the aortic and pulmonary valves best heard?
- How do the sounds of the heart valves reach the chest wall?

(For solutions see Appendix).

Chapter 8

Blood Vessels of Thorax

Frequently Asked Questions

- Discuss the arch of aorta and its branches.
- Write notes on: (a) Ascending aorta, (b) Bronchial arteries, (c) Coronary sinus.
- Write briefly on: (a) Great cardiac vein, (b) Left subclavian artery, (c) Left coronary artery and its branches, (d) Veins of heart.

The blood vessels of thorax include all the major arteries and veins entering and leaving the heart. These are the pulmonary arteries and veins, the ascending aorta, the arch of aorta and its branches, the descending aorta and the superior vena cava with its tributaries.

PULMONARY TRUNK AND ARTERIES

Pulmonary Trunk

The pulmonary trunk arises from the right ventricle, above and to the left of the supraventricular crest, the junction between the two being guarded by the pulmonary valve. The trunk runs upwards and backwards and ends by dividing into the right and left pulmonary arteries (Fig. 8.1). The lower end of the trunk lies opposite the sternal end of the left third costal cartilage. Its upper end (bifurcation) lies in front of the fifth thoracic vertebra. The lower part of the trunk lies in front of and to the left of the ascending aorta; and higher up on the left side of the latter (Fig. 8.2). The two vessels are enclosed in a common sheath of serous pericardium. The bifurcation of the pulmonary trunk lies below the arch of the aorta (Fig. 8.1).

Development

Both the pulmonary trunk and aorta are enclosed in a common sheath of visceral pericardium, as they both develop from the truncus arteriosus. They are separated from the left atrium by the transverse sinus of pericardium.

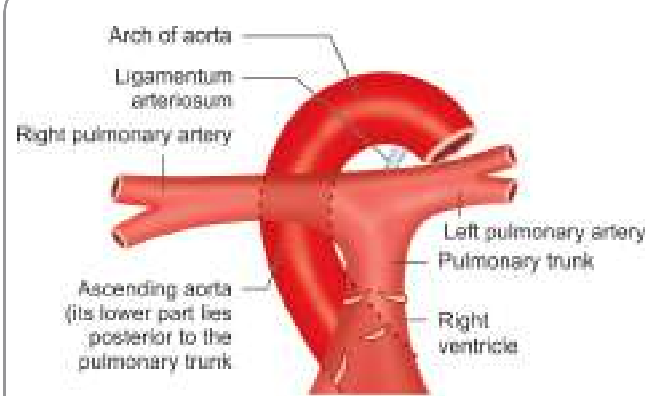


Fig. 8.1: Diagram to show the pulmonary trunk and pulmonary arteries and their relationship to the aorta

Right Pulmonary Artery

The right pulmonary artery arises from the upper end of the pulmonary trunk (Fig. 8.1) and has a long intrapericardial course as compared to the left pulmonary artery. It then runs to the right to reach the hilum of the right lung and is present antero-inferior to the eparterial bronchus. Here, it divides into two main branches. The upper branch is smaller and supplies the upper lobe of the right lung and the lower branch is larger and supplies the lower lobe. Each of these branches subdivides to accompany the segmental branches of the corresponding bronchi and hence reach the bronchopulmonary segments.

Relations

The ***relations*** of the artery are shown in Figure 8.2. Anterior to it, are the ascending aorta, the superior vena cava and the upper right pulmonary vein. Behind it, are the oesophagus and the right bronchus.

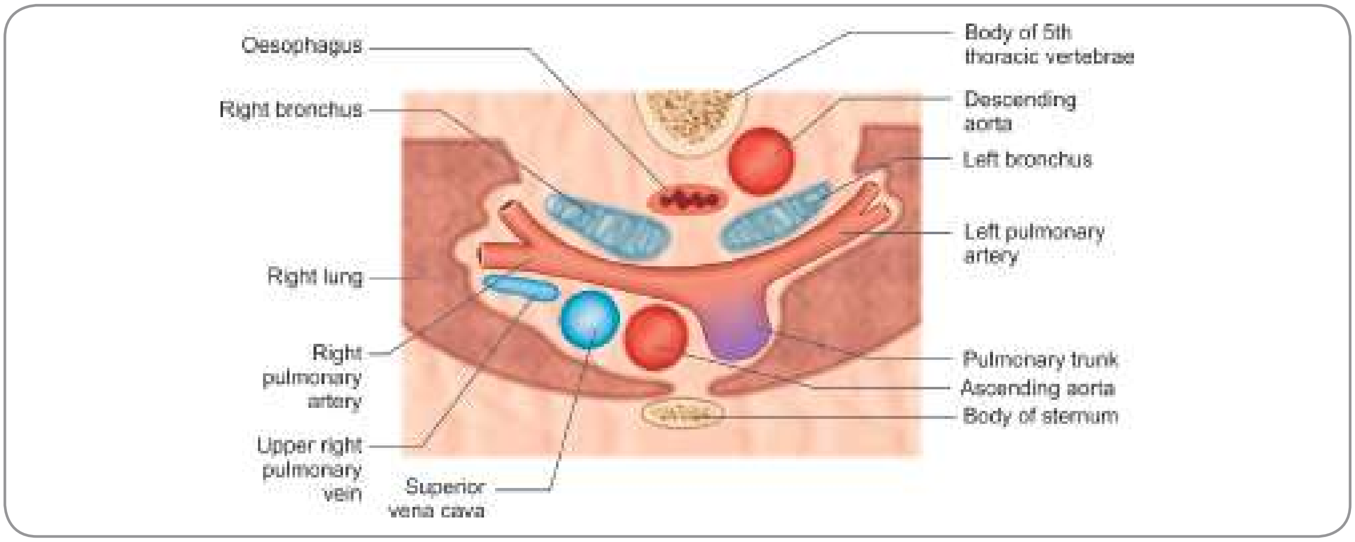


Fig. 8.2: Diagram to show the relations of the uppermost part of the pulmonary trunk and of the pulmonary arteries. (TS at the level of vertebra T5)

Left Pulmonary Artery

The left pulmonary artery arises from the upper end of the pulmonary trunk (Fig. 8.1) and runs to the left to reach the hilum of the left lung. At the hilum, it is present antero-superior to the principal bronchus. Here, it divides into two main branches that are distributed to the two lobes of the left lung equally.

Relations

The ***relations*** of the artery are shown in Figure 8.2. It is related posteriorly to the left bronchus and to the descending aorta. Superiorly, it is connected to the arch of aorta by the ligamentum arteriosum (Fig. 8.1).

Clinical Correlation

Patent Ductus Arteriosus

In the foetus, the ductus arteriosus connects the left pulmonary artery to the arch of aorta just distal to the origin of the left subclavian artery. Normally, the ductus is obliterated very soon after birth. If the ductus remains patent after birth, blood from the aorta enters the pulmonary arteries. As a result, the pulmonary circulation is overloaded and the left ventricle has to work harder and undergoes hypertrophy. If untreated, the condition may end in cardiac failure. The patent ductus can be closed surgically.

AORTA

The heart distributes blood to the entire body through an elaborate arterial tree. The 'main stem' of this tree is called the ***aorta.*** The aorta arises from the left ventricle of the heart, the junction between the two being guarded by the aortic valve. The aorta is the largest artery in the body. At its origin, it is about 3 cm in diameter.

For convenience of description, it is divided into the ***ascending aorta***, the ***arch of aorta*** and the ***descending aorta***. The descending aorta is divisible into the ***descending thoracic aorta*** and the ***abdominal aorta*** (Fig. 8.3).

Ascending Aorta

The ascending aorta is about 5 cm in length and 3 cm in diameter. The origin of the ascending aorta ('a' in Figure

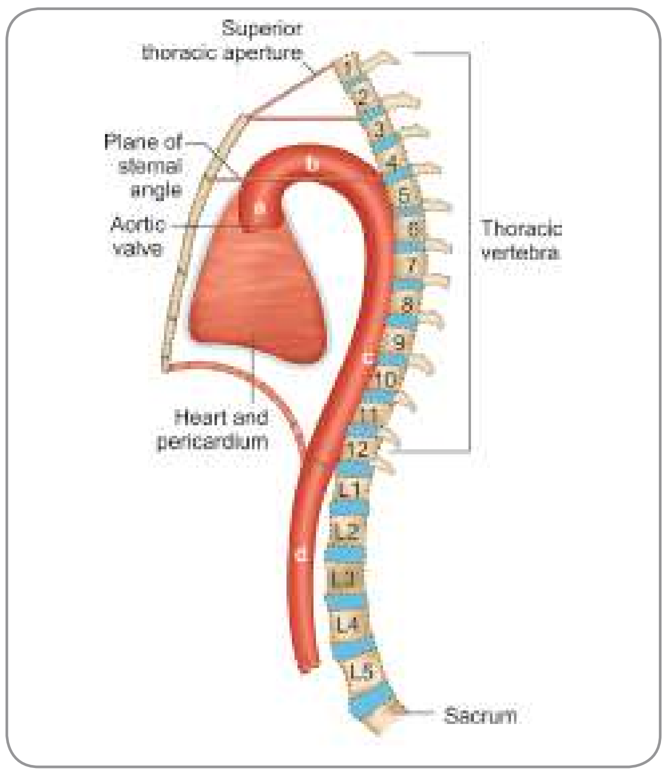


Fig. 8.3: Scheme to show the parts of aorta as seen from the left side

Key: a. Ascending aorta **b.** Arch of aorta **c.** Descending thoracic aorta **d.** Abdominal aorta

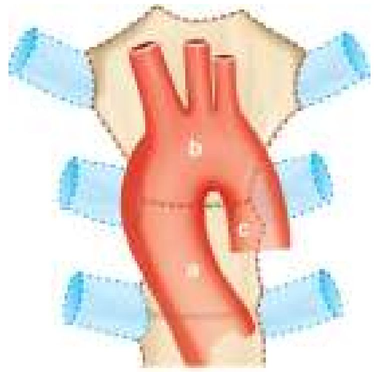


Fig. 8.4: Relationship of ascending aorta and arch of aorta to the sternum as viewed from the front

Key: a. Ascending aorta **b.** Arch of aorta **c.** Descending aorta

8.3, 8.4) from the left ventricle is situated behind the left half of the body of sternum at the level of the third intercostal space (Fig. 8.4). From here it passes upwards, forwards and to the right up to the junction of the body of sternum with the manubrium sterni (sternal angle). The ascending aorta, thus, lies within the middle mediastinum. It is surrounded by pericardium.

Just above the aortic valve, the wall of the ascending aorta is marked by three dilatations called the ***aortic sinuses***—one anterior, and two (right and left) posterior (Fig. 8.9). The anterior aortic sinus gives origin to the right coronary artery and left posterior aortic sinus gives origin to the left coronary artery. The right posterior is the non-coronary sinus. At the junction of the ascending aorta with the arch, the right wall of the vessel bulges outwards to form the bulb of the aorta. The only branches of the ascending aorta are the right and left coronary arteries which supply the heart.

Relations

The relations of the ascending aorta are as follows:

- ***Anteriorly***, the ascending aorta is related, in its upper part to the right lung and pleura. Its middle part is related to the pulmonary trunk. The lowest part is related to the auricle of the right atrium and part of the atrium proper, and to the infundibulum of the right ventricle.
- ***Posteriorly***, the ascending aorta is related (in its upper part) to the right pulmonary artery and the right principal bronchus and lower down to the left atrium.
- ***To the right*** of the ascending aorta, in the upper part is the superior vena cava, and lower down is the right atrium.
- ***To the left side,*** in the upper part is the pulmonary trunk and lower down, is part of the left atrium.

> **Clinical Correlation**
>
> **Aortic Aneurysms**
>
> A dilatation of a segment of aorta is referred to as ***aneurysm***. The dilatation may be fusiform or may take the form of a sac attached to the main vessel. In the ascending aorta, aneurysm can occur in the bulb. It can lead to rupture and to haemopericardium.

Arch of Aorta

The arch of aorta is located in the superior mediastinum. It is the continuation of the ascending aorta and subsequently continues as the descending thoracic aorta. The beginning and the ending of the arch of aorta takes place at the level of T4 vertebra or the level of sternal angle. It begins at the upper border of the second right sternocostal joint ('b' in Figure 8.4) and passes backwards and to the left of T4 vertebra in front of trachea, forming a convexity directed upwards. It curves around the hilum of the left lung and ends at the level of the sternal end of the second costal cartilage. The summit of the arch reaches the level of the middle of the manubrium.

The diameter of arch of aorta is the same as ascending aorta (3 cm) at origin but it becomes lesser near its termination (2 cm). At its junction with the descending aorta, a small constriction called the aortic isthmus is seen; the isthmus is immediately followed by a dilatation.

Relations

The structures related to the arch of aorta can be divided into those which lie anteriorly and to the left, to those which lie posteriorly and to the right (Fig. 8.5), to those which are above and to those which are below (Fig. 8.6).

- ***Anteriorly and to the Left***
  - Left lung and pleura
  - Left vagus and left phrenic nerves
  - Left superior intercostal vein
  - Smaller nerves—superior cervical cardiac branch of the left sympathetic trunk and the inferior cervical cardiac branch of the left vagus nerve.
- ***Posteriorly and to Right*** (from behind forwards)
  - Vertebral column
  - Oesophagus
  - Trachea
  - Superior vena cava
  - Small structures—the thoracic duct, the left recurrent laryngeal nerve and the deep cardiac plexus (Fig. 8.5).
- ***Above the arch of the aorta***, are the branches arising from the arch itself which are as follows (Fig. 8.6):
  - Brachiocephalic artery
  - Left common carotid artery
  - Left subclavian artery (Fig. 8.6)
  - These arteries are crossed just above the arch by the left brachiocephalic vein.
- ***Below the arch of aorta (Fig. 8.6)***
  - Bifurcation of pulmonary trunk
  - Left principal bronchus
  - Ligamentum arteriosum (which connects the left pulmonary artery to the arch)
  - Left recurrent laryngeal nerve that winds around the ligamentum arteriosum and then below the arch of aorta to reach its right side.

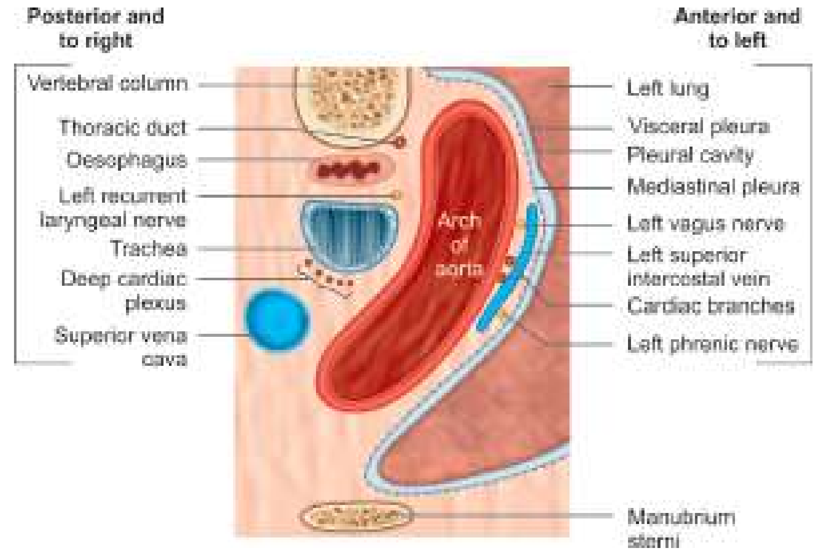


Fig. 8.5: Transverse section through the arch of aorta and surrounding structures

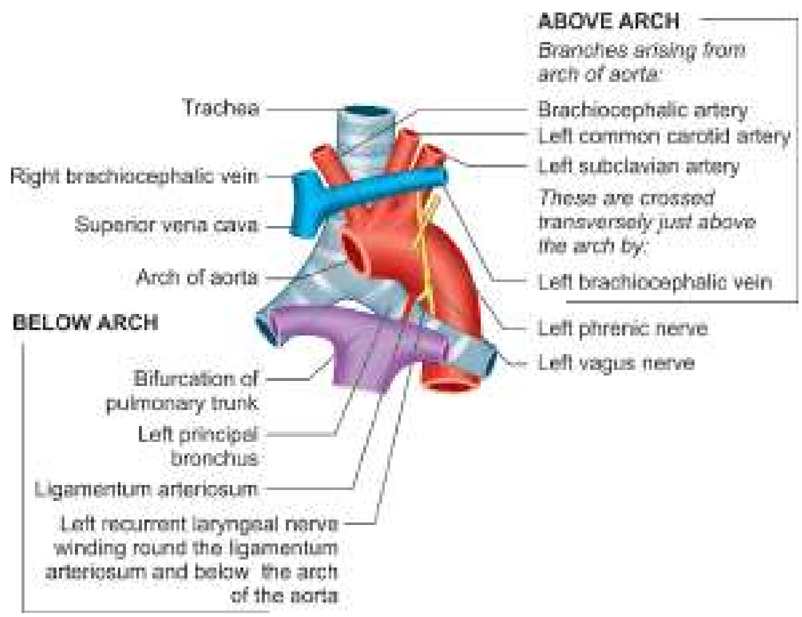


Fig. 8.6: Diagram to show the structures above and below the arch of aorta

Branches

The arch of aorta gives rise to its branches from its convexity, namely brachiocephalic artery, left common carotid artery and left subclavian artery. Occasionally, a small artery supplying the thyroid gland called the arteria thyroidea ima may arise from the arch of aorta.

Clinical Correlation

- ***Aortic aneurysm:*** Dilatation of aortic arch can happen. In some cases, an aneurysm splits the wall of the aorta into two layers (***dissecting aneurysm***). Surgical repair of an aortic aneurysm is possible.

contd…

Clinical Correlation *contd…*

- ***Aortic knuckle:*** In posterior-anterior view of a chest radiogram, the arch of aorta can be seen as a projection just above the left border of heart. This is called the aortic knuckle. If the knuckle is very prominent, hypertension may be suspected in the individual.
- ***Aortic window:*** In left anterior oblique view of chest radiogram, there is a pale space called the aortic window below the arch of aorta. In this space, the pulmonary trunk and the left pulmonary artery may be visualised.

Descending Aorta

The descending thoracic aorta ('c' in Figures 8.3 and 8.4) is continuous with the lower end of the arch. It descends in front of the thoracic verterbrae gradually passing from the left side towards the median plane. At the level of the lower border of the twelfth thoracic vertebra, it passes through the aortic orifice of the diaphragm to enter the abdomen. The descending thoracic aorta becomes continuous with the ***abdominal aorta*** ('d' in Figure 8.3) that descends in front of the lumbar vertebrae. It terminates in front of the fourth lumbar vertebra by dividing into two terminal branches called the ***common iliac arteries***.

Relations

Relationship to Vertebral Column

The upper end of the descending thoracic aorta lies at the upper border of the fifth thoracic vertebra (Fig. 8.7). Here, the aorta lies to the left of the vertebral column. It descends gradually passing to the front of the vertebrae. Its lower end lies in front of the lower border of the twelfth thoracic vertebra. The hemiazygos vein passes from left to right between the aorta and the vertebral column.

Relationship to the Oesophagus

After passing deep to the arch of aorta, the oesophagus lies to the right of the upper end of the descending aorta.

The oesophagus gradually passes to the front of the aorta. Its lower end lies in front, and to the left, of the aorta (Fig. 8.7).

Relationship to Root of Lung

The structures comprising the root of the left lung cross in front of the upper part of the descending aorta.

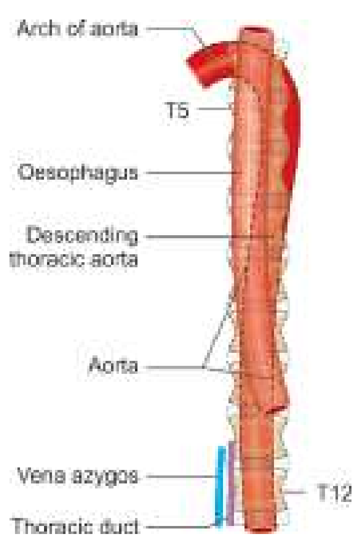


Fig. 8.7: Diagram to show relationship of the aorta to the vertebral column and to the oesophagus

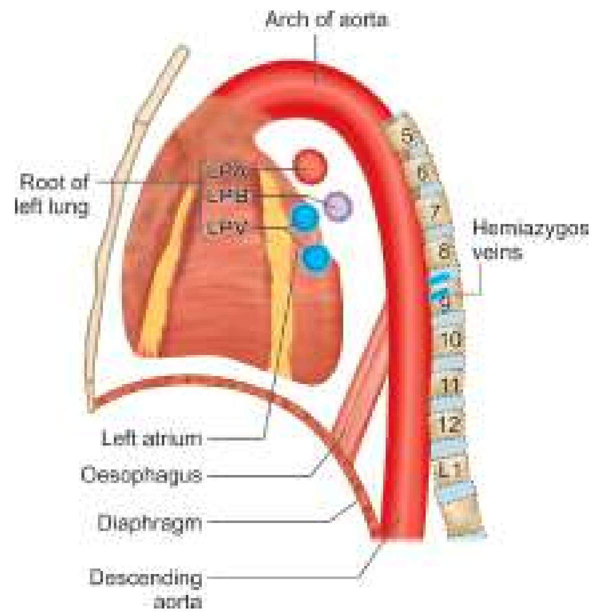


Fig. 8.8: Schematic diagram to show some relations of the descending thoracic aorta

Key: LPA. Left pulmonary artery **LPB.** Left principal bronchus **LPV.** Left pulmonary veins

Anterior Relations

The ***anterior relations*** of the descending thoracic aorta are (Fig. 8.8) (from above downwards):

- The root of the left lung consisting of the left pulmonary artery (LPA), the left principal bronchus (LPB) and the left pulmonary veins (LPV).
- The left atrium of the heart separated by the fibrous pericardium and the oblique sinus
- The oesophagus
- The diaphragm

Structures

Structures to the Right Side

- Oesophagus (in the upper part) (Fig. 8.7)
- Thoracic duct
- Vena azygos
- The upper part of the aorta is separated from the right lung and pleura by the oesophagus, but its lower part is in contact with them.

Structures to the Left Side

Left lung and pleura

Clinical Correlation

Coarctation of Aorta

This term refers to a condition in which the aorta is abnormally narrow near the attachment of the ligamentum arteriosum. Coarctation may be of two types:

contd...

Clinical Correlation *contd...*

- The ***preductal*** type is common in infants. The narrowing is proximal to the attachment of the ductus arteriosus that usually remains patent and feeds blood to the part of the aorta distal to the coarctation. As this blood is unoxygenated, the lower part of the body shows cyanosis.
- In the ***postductal*** variety, seen in adults, the ductus arteriosus is usually not patent. Blood reaches the distal part of the body through an elaborate collateral circulation. Part of this collateral circulation is through the intercostal arteries. Blood enters them through the internal thoracic artery and flows backwards in them to reach the thoracic aorta. These arteries enlarge and produce a characteristic notching of ribs that can be seen in a skiagram.

When coarctation is present, there is hypertension in the part of the body supplied by branches arising above the level of constriction, and hypotension in parts supplied by branches arising below the level of constriction. Hence, blood pressure recorded from the upper limbs is much higher than that recorded from the lower limbs. The pulse in the femoral artery will be felt a little later than that in radial artery if both are palpated at the same time (Radio femoral delay). Coarctation can be surgically corrected by removing the narrow segment and by anastomosing the two cut ends of the aorta.

Branches of Aorta

The aorta gives off a large number of branches in the thorax. These are shown in Figure 8.9. Some of the branches are large and have a wide distribution, while others are small.

Coronary Arteries

The coronary arteries supply blood to heart. They arise from the ascending aorta. There are two—right and left, coronary artery.

Course of Right Coronary Artery

The ***right coronary artery*** arises from the anterior aortic sinus of the ascending aorta (Fig. 8.9). It supplies most of right atrium, right ventricle, conducting system and the atrioventricular groove. For convenience of description, the artery may be divided into three parts. The first part passes forwards for a short distance between the pulmonary trunk (to its left) and the auricle of the right atrium (to its right).The second part runs downwards on the sternocostal surface of the heart between the right atrium and right ventricle (i.e., in the anterior part of the atrioventricular groove seen in Figure 8.10).

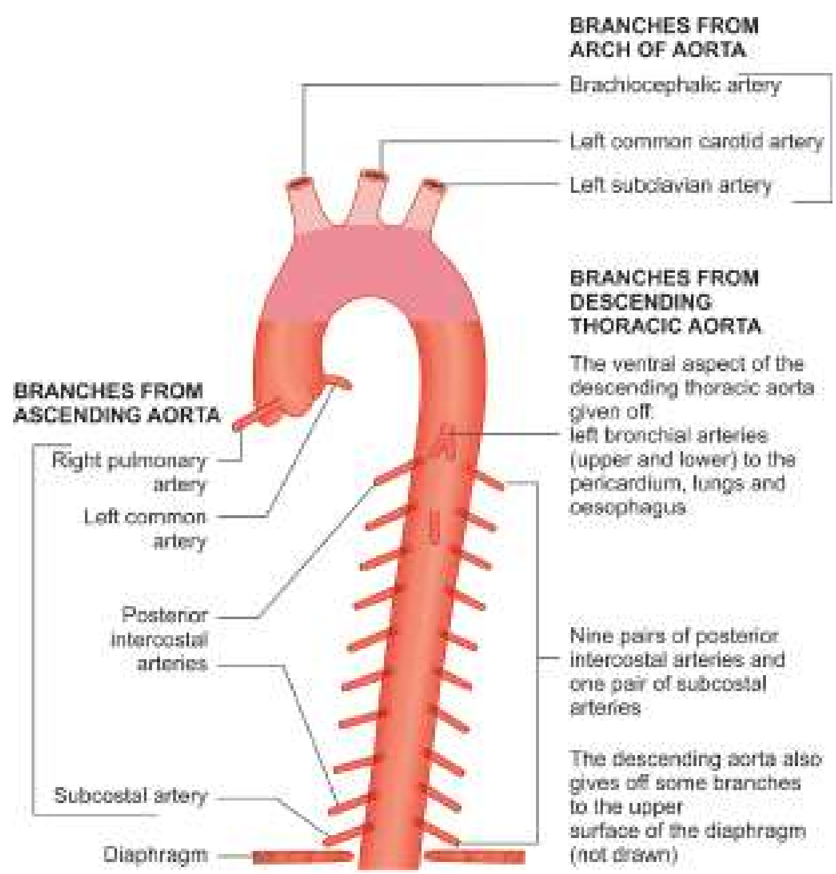


Fig. 8.9: Scheme to show branches arising from the aorta in the thorax

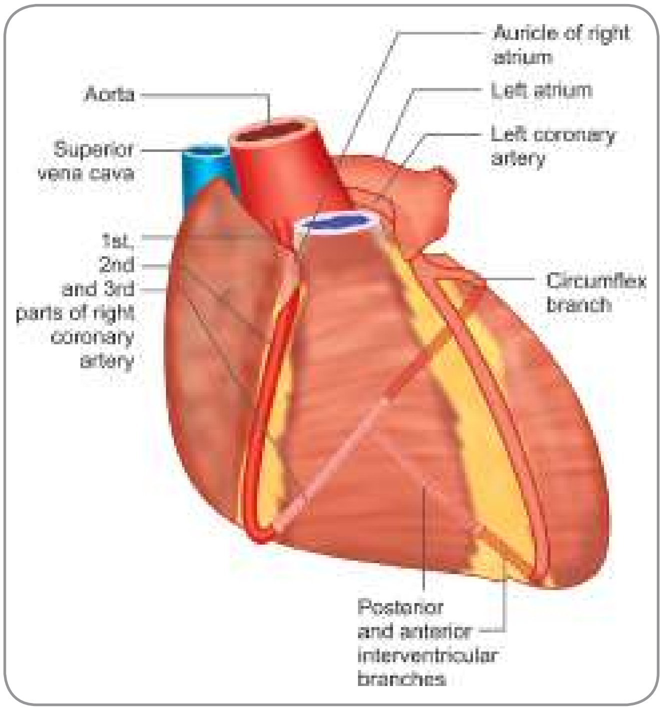


Fig. 8.10: Schematic diagram to show the coronary arteries and their interventricular branches

Reaching the inferior (or acute) margin of the heart the artery curves around it to become the third part, which lies in the posterior part of the atrioventricular groove (between the right atrium and ventricle). It runs upwards and to the left and ends by anastomosing with the circumflex branch of the left coronary artery just to the left of the crux of the heart (Fig. 8.10). Before its termination, it gives off the posterior interventricular branch that runs downwards, forwards and to the left in the posterior interventricular groove (Fig. 8.10).

Branches of the Right Coronary Artery

The first part of the artery gives off the following branches:

- The ***right conus artery*** is small and ramifies over the lower part of the pulmonary trunk and the upper part of the infundibulum (Fig. 8.11). If the conus artery arises as a separate branch from the right aortic sinus, it is called the third coronary artery. The right conus artery anastomoses with a similar branch of the left anterior descending artery (anterior interventricular artery) forming the annulus of Vieussens.
- The ***artery of the sinoatrial node*** passes backwards between the aorta and the auricle of the right atrium to reach the superior vena cava. It gives branches which form a ring around the vena cava and descend to supply the right atrium including the sinoatrial node.

The second part of the artery gives off a series of branches to the right atrium (Fig. 8.11), and to the anterior wall of the right ventricle. The largest of these branches runs along the lower border of the heart and is called the ***right marginal branch.***

The third part of the artery also gives off atrial and ventricular branches to the right atrium and to the diaphragmatic wall of the right ventricle. One of the atrial branches supplies a part of the wall of the left atrium**.**

The posterior interventricular branch of the right coronary artery gives off branches to the diaphragmatic wall of the right ventricle; and some to the left ventricle. Some branches run upwards and forwards into the posterior one-third of the interventricular septum. Its septal branch

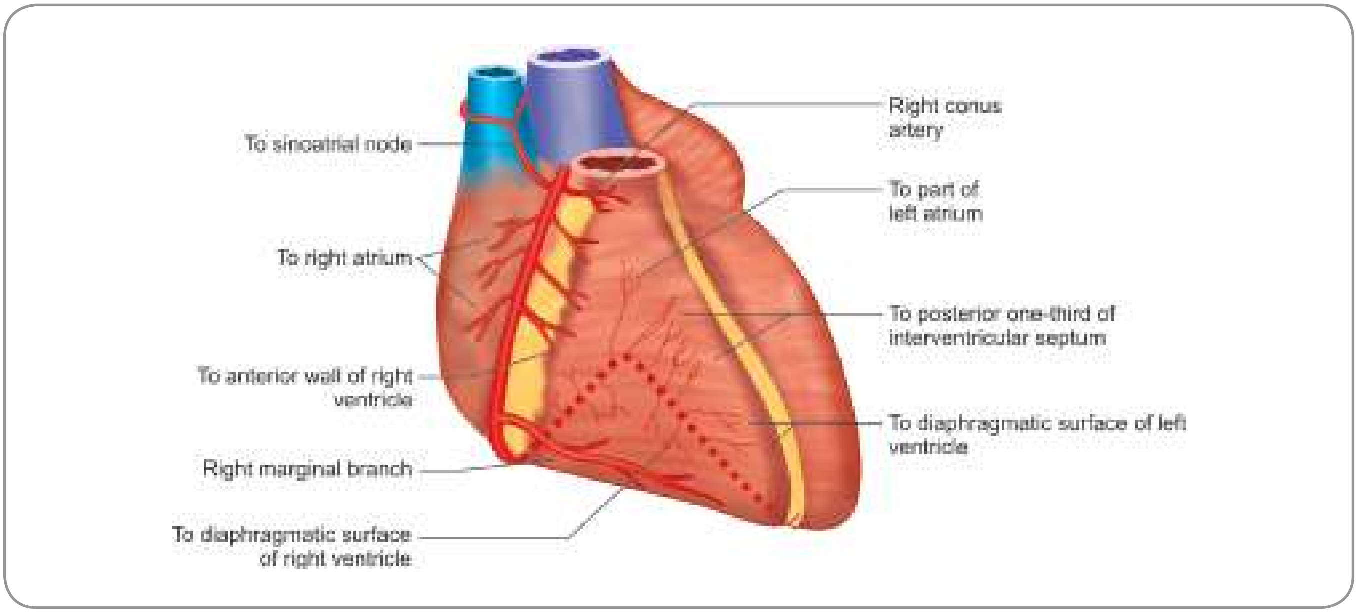


Fig. 8.11: Scheme to show the distribution of the right coronary artery

often supplies the atrioventricular (AV) node of the heart. The origin of posterior interventricular artery determines the coronary dominance of the heart. If it originates from the right coronary artery, it is called right dominance and if from the circumflex branch of the left coronary artery, it is called left dominance. In balanced hearts, both the arteries give rise to two posterior interventricular arteries, both of which are seen in the posterior interventricular groove.

Course of Left Coronary Artery

The ***left coronary artery*** arises from the left posterior sinus of the ascending aorta (Fig. 8.9). It supplies the left ventricle, left atrium, part of right ventricle and anterior two-thirds of the interventricular septum. It passes to the left between the pulmonary trunk and the left atrium and appears on the sternocostal surface of the heart after passing deep to the auricle of the left atrium (Fig. 8.10). Here, the artery divides into two main branches which are more or less equal in diameter. These are the ***circumflex*** and ***anterior interventricular*** arteries.

Branches of the Left Coronary Artery

The branches of the left coronary artery are its terminal branches and the branches given thereof (Fig. 8.12).

- ***Circumflex artery:*** The circumflex branch runs to the left in the anterior part of the atrioventricular groove (between the left atrium and the left ventricle, Figure 8.10). It then curves around the left border of the heart and runs downwards and to the right in the posterior part of the same groove. It ends by anastomosing with the terminal part of the right coronary artery.

The ***circumflex branch*** gives off several branches to the wall of the left ventricle. One of these branches is specially prominent. It is called the ***left marginal artery***. It runs down along the rounded left margin of the heart and supplies it. The circumflex artery also gives some branches to the diaphragmatic surface of the left ventricle. Almost the whole of the left atrium is supplied by branches of the circumflex artery. One of these branches sometimes passes across the back of the left atrium to reach the sinoatrial (SA) node. When present, it replaces the branch to the node from the right coronary artery. Instead of ending in the atrioventricular groove, the circumflex branch may continue into the posterior interventricular groove replacing the posterior interventricular branch of the right coronary as shown in figure 8.13A and B (Condition of Left coronary dominance).

- ***Anterior interventricular artery (Left anterior descending artery):*** The anterior interventricular branch runs downwards and to the left in the anterior interventricular groove (i.e., between the right and left ventricles) (Fig. 8.12). Near the apex of the heart it curves around the lower border and runs for a short distance in the posterior interventricular groove where it ends by anastomosing with the posterior interventricular branch of the right coronary artery (Fig. 8.10).

The ***anterior interventricular artery*** gives off several large branches to the anterior wall of the left ventricle (Fig. 8.12).

One of these is specially prominent and runs downwards and to the left between the anterior interventricular and circumflex arteries. It is called the ***diagonal*** branch. Sometimes the diagonal branch arises directly from the trunk of the left coronary artery. The anterior interventricular branch also gives off a few small branches to the right ventricle. One of these ramifies on the infundibulum and is called the ***left conus artery.*** It anastomoses with the right conus artery.

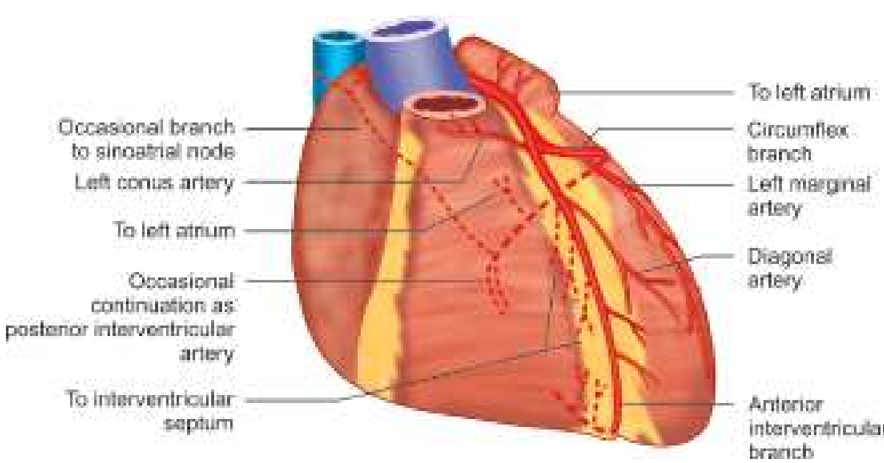


Fig. 8.12: Scheme to show the distribution of the left coronary artery–some small branches given by the anterior interventricular branch to the right atrium are not drawn for sake of clarity

The anterior interventricular branch also sends several branches downwards into the interventricular septum. They supply the anterior two-thirds of the septum. Some branches to the septum arise from the terminal part of the artery after it has entered the posterior interventricular groove.

Added Information

The right coronary artery and the left coronary artery (along with its circumflex branch) form an arterial ring lying in the atrioventricular groove. This ring is responsible for the name 'coronary' (meaning crown). It resembles a crown fitted to the heart.

Areas of Distribution

From the distribution of the right and left coronary arteries, it can be understood that the right atrium and ventricle are supplied mainly by the right coronary artery, and the left atrium and ventricle by the left coronary artery. However, small parts of each ventricle, and of the left atrium are supplied by the artery of the opposite side.

The anterior two-thirds of the interventricular septum is supplied by the left coronary artery, and its posterior one-third by the right coronary artery. The SA node, the AV node, the AV bundle and the proximal parts of its right and left branches are supplied by the right coronary artery. The distal parts of the bundle branches are supplied by the left coronary artery.

Clinical Correlation

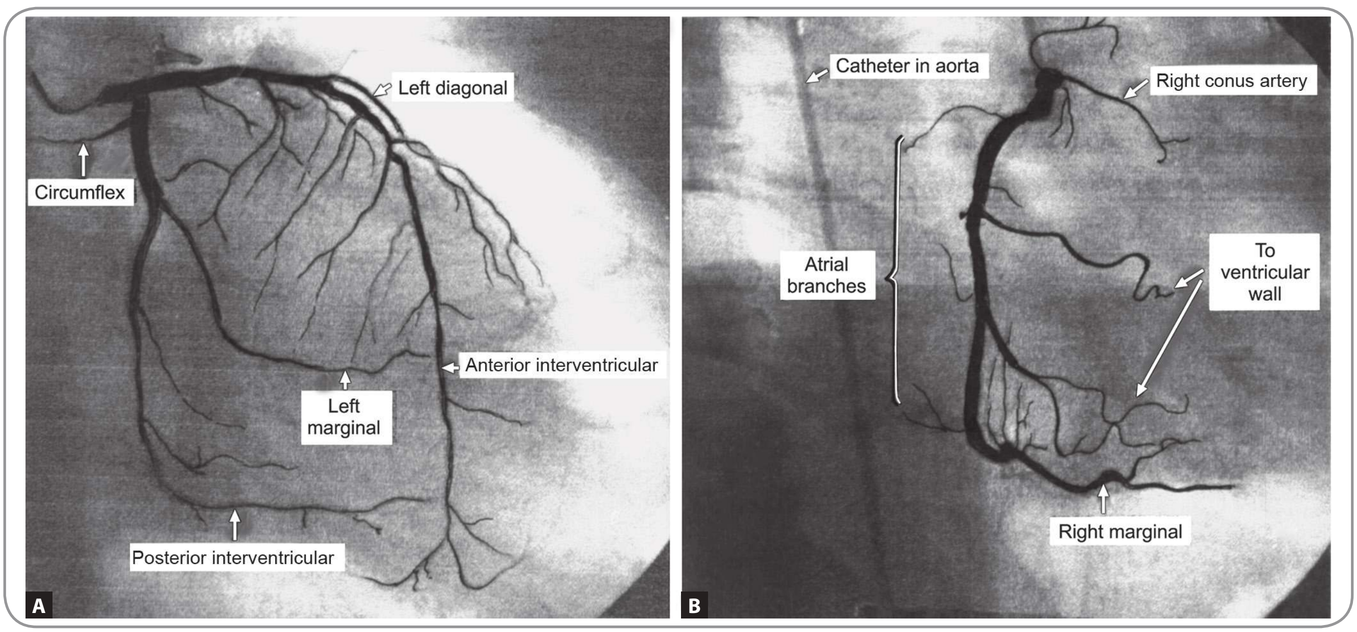
Coronary Angiography

The coronary arteries and their branches can be visualised by coronary angiography and sites of narrowing determined (Figs 8.13A and B). In this connection, it is necessary for the student to know that the nomenclature used in clinical texts for some branches of the coronary arteries are different from those in textbooks of anatomy. These differences are as follows:

- The anterior interventricular branch of the left coronary artery is described as the ***Left Anterior Descending branch (LAD)***.
- The posterior interventricular branch of the right coronary artery is described as the ***posterior descending branch***.
- The right marginal branch of the right coronary artery is named the ***acute marginal branch***.
- The left marginal branch of the left coronary artery (which may be multiple) is referred to as the ***Obtuse Marginal branch (OMA)***.

Myocardial infarction

When there is significant narrowing of the coronary vessels or their branches, there can be ischaemia of the myocardium, resulting in severe gripping pain. This condition is called angina pectoris. This can aggravate to complete loss of blood supply and may even become fatal causing myocardial infarction. The condition can be treated either by Percutaneous Transluminal Coronary Angioplasty (PTCA) where a balloon catheter is introduced to dilate the narrowing and a stent placed to prevent any further narrowing or by Coronary Artery Bypass Graft (CABG) where a graft (another blood vessel or an artificial tube) is placed bypassing the narrowed vessel.



Figs 8.13A and B: Coronary angiography. Oblique views. A catheter is passed into the femoral artery, and upwards to reach the aorta. Its tip is then made to enter one coronary artery and a contrast medium injected. The left coronary artery and its branches are seen in **A**, and the right coronary artery in **B.** Both figures are from the same person. In this case the posterior interventricular branch is derived from the left coronary artery (instead of the more common derivation from the right coronary). Such a condition is referred to as left dominance

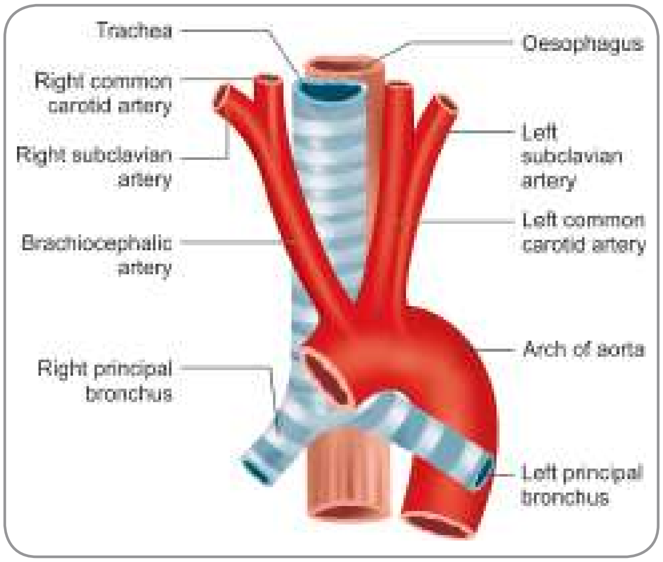


Fig. 8.14: Diagram to show the branches of the arch of the aorta

Branches of the Arch of Aorta

These are the brachiocephalic, left common carotid and left subclavian arteries. The branches of the arch of the aorta are shown in Figure 8.14. They are meant for distribution of blood to the head and neck and to the upper limbs. They reach the head and neck by passing through the superior mediastinum of the thorax. Their course and relations here are important and are considered below. All these arteries arise from the summit of the arch of aorta that lies at the level of the middle of the manubrium sterni (or the disc between the third and fourth thoracic vertebrae).

Brachiocephalic Artery

This is the first branch of the arch of aorta. Its origin lies more or less in the median plane, in front of the trachea. From here, it runs upwards and backwards and as it does so, it winds around the trachea to reach the right side of the latter. It ends behind the right sternoclavicular joint by dividing into the right common carotid and right subclavian arteries.

Relations

- ***Anterior***
  - The manubrium sterni
  - The sternoclavicular joint of the right side
  - The right sternohyoid and sternothyroid muscles
  - The remnants of the thymus
  - The left brachiocephalic vein.
- ***Posterior***
  - The trachea
  - Right pleura and lung
  - The right vagus nerve.
- ***On its right side***
  - The right brachiocephalic vein
  - The upper part of the superior vena cava
  - The right lung and pleura.
- ***On its left side***
  - The remnants of the thymus
  - The inferior thyroid veins
  - The left common carotid artery
  - The trachea.

Development

- ***Arterial system:*** The primitive embryonic arteries are the right and left primitive aortae. They pass around the developing foregut and run on the dorsolateral aspects of the latter as the dorsal aortae. On each side, therefore, a short ventral aorta, an aortic arch and a dorsal aorta are present. The truncus arteriosus of the developing heart expands to become the aortic sac and during this expansion, encompasses the ventral aortae. Therefore, at the next stage, there are no ventral aortae but the aortic arches directly arise from the aortic sac. All the complicated patterns of arterial distribution are derived from this simple arrangement of truncus, aortic arches and the dorsal aortae. Meanwhile the developing heart shifts caudally due to the development of other structures. The single pair of aortic arches is supplemented by the development of five more pairs. All the pairs are not present simultaneously. By around the 4th week, the sixth pair of aortic arches develop in the sixth arch mesoderm. They give branches to the plexuses of vessels found in the lung buds and are hence called the pulmonary arches. Each dorsal aorta develops a cranial extension. The two dorsal aortae also fuse at their caudal portions into a single vessel.

  By the 2nd month, the 3rd, 4th and 6th aortic arches are well developed though the 5th arch made only a transient appearance and disappeared; the 1st disappeared and the 2nd has turned rudimentary with partial disappearance. Meanwhile, the truncus gets subdivided by a spiral septum. The distal portion of this septum extends into the aortic sac; differential and rotational growth lead to the following situation:
  - The right ventricle empties into the dorsal part of the aortic sac and thence to the pulmonary arch arteries;
  - The left ventricle empties into the ventral part of the aortic sac and thence to the 3rd and 4th arch arteries.

    Several changes take place after this. The summary deduced from this development with regard to the arteries of the thorax is as follows:
    - The aortic sac, its left horn and the 4th arch artery form the aorta.
    - The right horn of aortic sac elongates and becomes the brachiocephalic artery (called the innominate artery in olden times). The right 3rd and 4th arch arteries receive blood from it and become the right common carotid and stem of right subclavian arteries respectively.
    - The proximal part of the 3rd arch artery becomes the left common carotid artery.
    - The left seventh cervical intersegmental artery becomes the stem of the left subclavian artery.
    - A portion of the ventral division of the seventh cervical intersegmental artery becomes the internal thoracic artery.

contd...

Development ***contd...***

- ***Venous system:*** An equally, if not more, complicated pattern of venous development also occurs, the details of which are beyond the purview of this discussion. An essential summary is as follows:
  - The right duct of Cuvier and the terminal portion of the right anterior cardinal vein become the superior vena cava.
  - The medial sympathetic venous plexus lines (which form on the medial aspect of the sympathetic trunk in the early embryo) give rise to the azygos venous system.

Left Common Carotid Artery

The left common carotid artery arises from the arch a little to the left of the brachiocephalic artery. Its origin also lies in front of the trachea. From here, it passes upwards winding around the trachea to reach the left side of the latter. It enters the neck by passing deep to the left sternoclavicular joint.

Relations of Thoracic Part

- ***Anterior***
  - The manubrium sterni
  - The left sternohyoid and sternothyroid muscles
  - The remnants of the thymus
  - The left brachiocephalic vein.
- ***Posterior***
  - The trachea
  - The left subclavian artery
  - The left vagus and left phrenic nerves.
- ***On its right side***
  - The brachiocephalic artery
  - Trachea.
- ***On its left side***
  - The left lung and pleura
  - The left vagus and phrenic nerves.

Left Subclavian Artery

The left subclavian artery arises from the arch of aorta a little to the left of and behind the left common carotid artery, the origin lying to the left of the trachea. The artery runs almost vertically along the left side of the trachea to enter the neck at the level of the left sternoclavicular joint, where it lies behind the common carotid artery.

Relations of Thoracic Part

- ***Anterior***
  - The left common carotid artery
  - The left brachiocephalic vein
  - The left vagus and phrenic nerves.
- ***Posterior***
  - The left lung and pleura
  - The left edge of the oesophagus
  - The left recurrent laryngeal nerve
  - The thoracic duct
- ***On the right side***
  - The trachea
  - The left recurrent laryngeal nerve
  - The oesophagus.
- ***On its left side***
  - The left lung and pleura.

Branches of Descending Thoracic Aorta

The branches of the descending thoracic aorta are shown in Figure 8.9. Apart from several small branches to the oesophagus, the pericardium, the diaphragm (phrenic branches) and to lymph nodes in the posterior mediastinum (mediastinal branches) it gives off the bronchial, posterior intercostal and subcostal arteries. The posterior intercostal and subcostal arteries are described in the chapter on walls of thorax. The bronchial arteries are described here.

Bronchial Arteries

These arteries supply the bronchi, the connective tissue of the lung and related lymph nodes. Generally, there are two left bronchial arteries: upper and lower. They arise from the front of the thoracic aorta. Usually, there is one right bronchial artery. It may arise from the upper left bronchial artery or from the third right posterior intercostal artery. The number and origin of bronchial arteries are subject to considerable variation.

Other Arteries in the Thorax

The ***internal thoracic artery*** and the ***superior intercostal artery*** arise in the neck and descend to the thoracic wall.

VEINS OF THORAX

The veins of thorax are as follows:

- ***Veins which drain the wall of thorax:*** These include the intercostal and subcostal veins, the azygos and hemiazygos veins, and the internal thoracic vein. These are dealt with in the chapter on walls of thorax.
- ***Veins which drain the heart:*** These are the coronary sinus and its tributaries and some small veins.
- ***Large veins present in the mediastinum:*** These are the superior vena cava, the right and left brachiocephalic veins, the inferior vena cava, and the pulmonary veins.

VEINS OF HEART

Coronary Sinus

Most of the veins draining the heart wall end in a wide vein, about two centimeters long, called the coronary sinus (Figs 8.15 and 8.16). This sinus lies in the posterior and left part of the atrioventricular groove i.e., along the posterior edge of the diaphragmatic surface of the left ventricle. Its right end opens into the right atrium where it is guarded

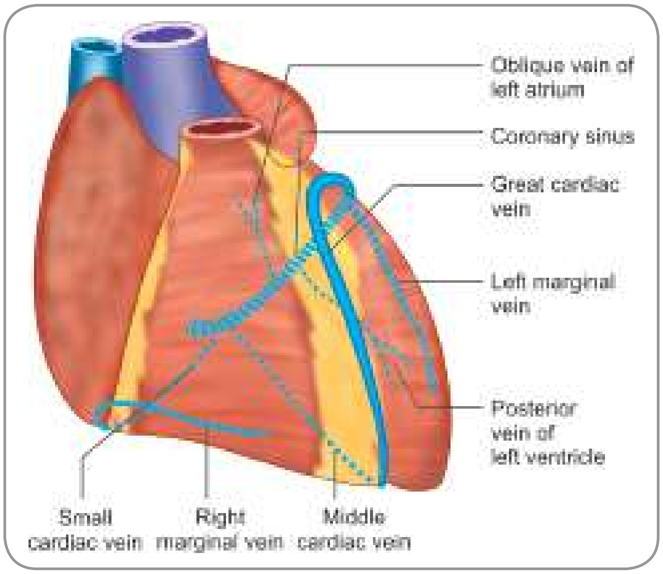


Fig. 8.15: Scheme to show veins of the heart as seen from the front Veins not normally seen from the front are drawn (in dotted lines) as if the walls of the chambers of the heart were transparent

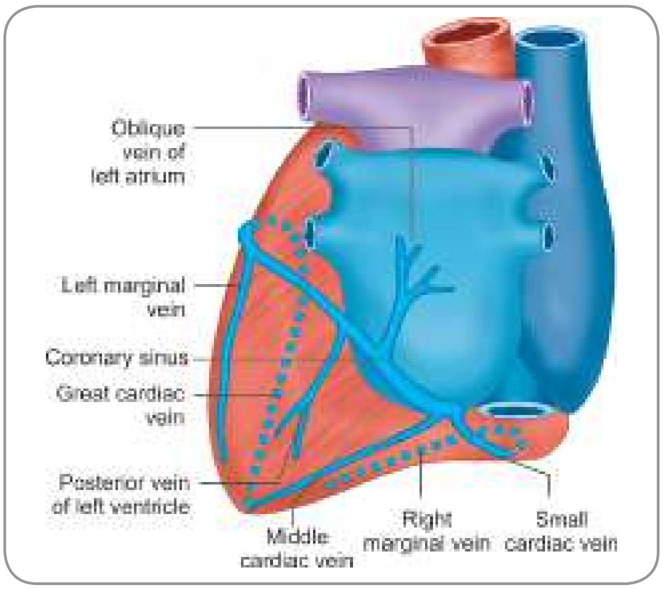


Fig. 8.16: Veins of the heart as seen from behind. Veins not normally seen from the back are drawn(in dotted lines) as if the walls were transparent

by a small Thebesian valve (named after the 17th–18th century German physician Adam Thebesius; also called the coronary valve or valve of coronary sinus).

The coronary sinus receives the following veins:

- The great cardiac vein
- The small cardiac vein
- The middle cardiac vein
- The posterior vein of the left ventricle
- The oblique vein of the left atrium (Figs 8.15 and 8.16).

Great Cardiac Vein

The great cardiac vein is seen mainly on the sternocostal aspect of the heart (Fig. 8.15). It ascends in the anterior interventricular groove (parallel to the anterior interventricular branch of the left coronary artery).

It turns to the left in the coronary sulcus (alongside the circumflex branch of the left coronary artery), winds around the left margin of the heart and ends in the left extremity of the coronary sinus. It receives a large left marginal vein which corresponds to the left marginal branch of the left coronary artery. It is usually named the great cardiac vein only after turning into the coronary sulcus.

Small Cardiac Vein

The small cardiac vein is situated at the junction of the base of the heart and its diaphragmatic surface (Figs 8.15 and 8.16). It lies in the posterior and right part of the coronary sulcus. It thus runs along side the terminal part of the right coronary artery. The small cardiac vein ends by joining the coronary sinus near its termination. It receives the ***right marginal vein*** which is seen on the sternocostal surface just above the inferior border of the heart. Its position thus corresponds to that of the right marginal branch of the right coronary artery.

Middle Cardiac Vein

The middle cardiac vein begins near the apex of the heart and runs backwards on the diaphragmatic surface (Figs 8.15 and 8.16). It lies in the posterior interventricular groove i.e., it accompanies the posterior interventricular branch of the right coronary artery. The vein ends in the coronary sinus near its termination.

Other Veins of the Heart

- The ***posterior vein of the left ventricle*** runs backwards on the diaphragmatic surface of the ventricle and ends in the coronary sinus.
- The ***oblique vein of the left atrium*** lies behind this chamber i.e., on the base of the heart (Its importance is that it represents a remnant of the left common cardinal vein).
- In addition to the above, some ***anterior cardiac veins*** lying on the right ventricle open into the right atrium. A number of small ***venae cordis minimae*** drain directly into the chambers of the heart.

Pulmonary Veins

There are four pulmonary veins, two each (superior and inferior), on the right and left sides. Each of them is formed by union of smaller veins draining the alveoli of the lungs. On the left side the superior and inferior veins drain the upper and lower lobes of the lung, respectively. The veins of the left side pass anterior to the descending aorta. On the right side the upper and middle lobes drain through the superior vein and the lower lobe through the inferior vein. The superior vein crosses behind the superior vena cava; and the inferior vein crosses behind the right atrium.

Superior Vena Cava

The superior vena cava is formed by the union of the right and left brachiocephalic veins. Large veins draining into the superior vena cava are illustrated in Figure 8.17. Its upper end is situated at the lower border of the first right costal cartilage. It descends behind the first intercostal space, the second costal cartilage and the second intercostal space to end at the level of the third right costal cartilage by opening into the right atrium. The vessel is about 7 cm long. The lower half of the vessel is enclosed within the fibrous pericardium. Apart from the brachiocephalic veins, the superior vena cava receives the azygos vein which joins it on the right side about its middle.

Relations

- ***To the right side*** the superior vena cava is related to:
  - The right lung and pleura
  - The right phrenic nerve descends in contact with the right side of the vena cava
- ***Anteromedially***, the vena cava is related to:
  - The ascending aorta
- ***Posteromedially***, it is related to:
  - The trachea
  - The right vagus nerve
- ***Anteriorly***, the superior vena cava is related to:
  - The internal thoracic artery
  - The 1st and 2nd costal cartilages
  - The anterior margin of the right lung.

Clinical Correlation

Obstruction of Superior Vena Cava

In obstruction to the superior vena cava, the azygos vein becomes an important channel for maintaining venous return from the upper part of the body. The lower end of the azygos

contd...

Clinical Correlation *contd...*

vein usually communicates with the inferior vena cava and at its upper end it opens into the superior vena cava at about its middle.

When the superior vena cava is obstructed above the entry of the azygos vein, blood from the upper half of the body reaches the intercostal veins through anastomoses between these veins and other veins of the region (including the internal thoracic vein). Through the intercostal veins, this blood passes into the azygos vein and into the superior vena cava.

When the superior vena cava is obstructed below the entry of the azygos vein, blood in the vena cava can pass through the azygos vein into the inferior vena cava and thence to the heart. Blood also passes through the superficial veins which connect the lateral thoracic vein (a tributary of the axillary vein) with the superficial epigastric tributary of the femoral vein. This connecting vein is the ***thoracoepigastric vein***.

The vertebral venous plexuses are also important channels of communication between the superior vena caval and inferior vena caval systems.

Right Brachiocephalic Vein

It is formed by union of the right internal jugular and subclavian veins. It ends by joining the left brachiocephalic vein to form the superior vena cava. The vein is about 2.5 cm long. Its upper end (beginning) lies behind the sternal end of the right clavicle; while its lower end (termination) lies at the level of the lower border of the first right costal cartilage.

Relations

- ***To its right side*** the right brachiocephalic vein is related to:
  - The right lung and pleura
  - The right phrenic nerve.

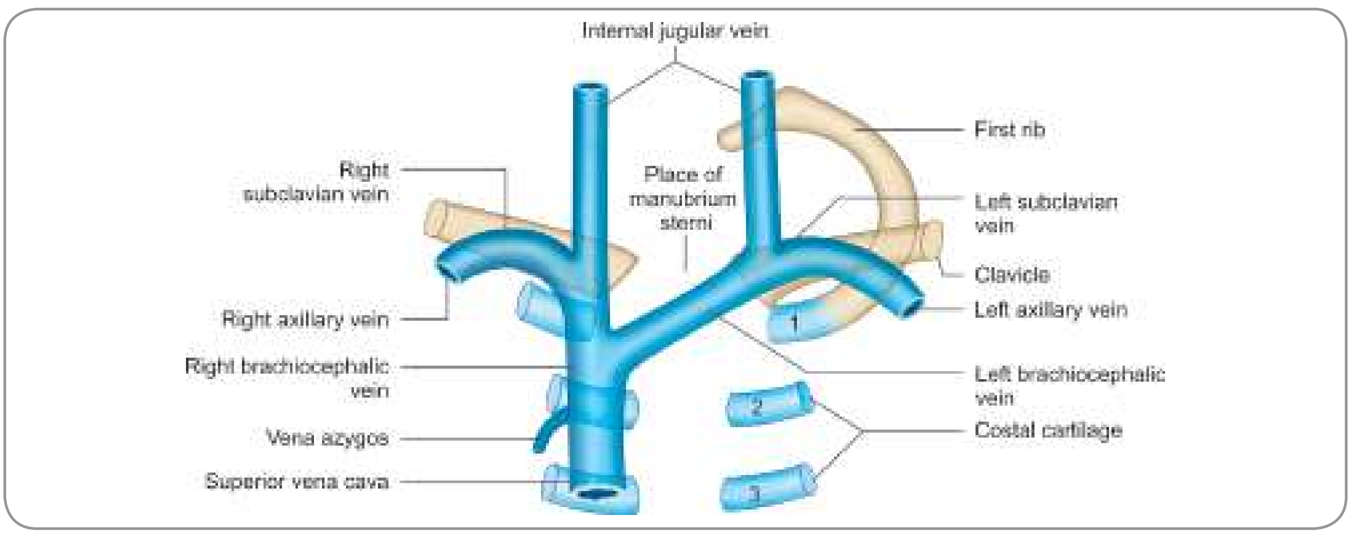


Fig. 8.17: Large veins draining into the superior vena cava—manubrium sterni has been removed to show the formation of SVC

- ***Posteromedially,*** the vein is related to:
  - The brachiocephalic artery
  - The right vagus nerve.
- ***Anteriorly,*** the vein is related to
  - The first costal cartilage
  - The sternal end of the clavicle.
- The ***tributaries*** of the right brachiocephalic vein are:
  - Right vertebral vein
  - Right internal thoracic vein
  - An inferior thyroid vein
  - Right first intercostal vein.

Left Brachiocephalic Vein

It is formed by union of the left internal jugular and subclavian veins. The vein begins behind the sternal end of the left clavicle. This vein is about twice as long as the right brachiocephalic vein as it has to run obliquely behind the manubrium to reach its termination at the lower border of the first right costal cartilage. Here, it joins the right brachiocephalic vein to form the superior vena cava.

Relations (Fig. 8.18)

- ***Anteriorly***
  - Manubrium sterni
  - Sternohyoid and sternothyroid muscles
  - Remnants of the thymus.

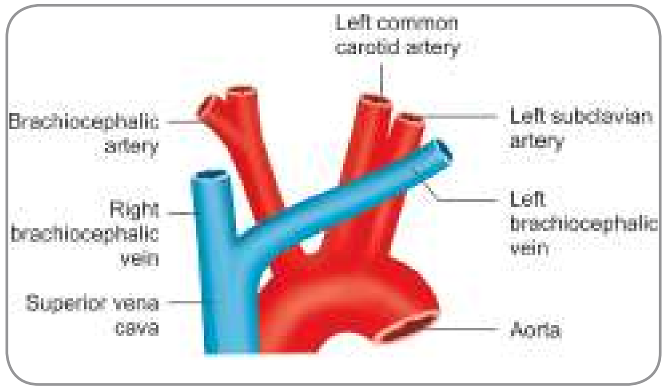


Fig. 8.18: Drawing to show the relationship of the left brachiocephalic vein to the arch of the aorta

- ***Posteriorly***
  - Arteries arising from the arch of the aorta i.e., the brachiocephalic, left common carotid and left subclavian arteries.
  - Trachea.
  - Left vagus and left phrenic nerves.
- The ***tributaries*** of the left brachiocephalic vein are:
  - The left vertebral vein
  - The left first intercostal vein
  - The left superior intercostal vein
  - An inferior thyroid vein.

Multiple Choice Questions

1. To the right of ascending aorta in the upper part is the:
   a. Right atrium
   b. Superior vena cava
   c. Pulmonary trunk
   d. Right principal bronchus

2. Coarctation of aorta usually involves that part of the aorta near:
   a. The summit of the arch
   b. The termination
   c. The junction of descending thoracic and abdominal parts
   d. The attachment of ligamentum arteriosum

3. The third coronary artery is the name given to:
   a. The right conus artery wherever it arises from
   b. The right conus artery if it arises separately from the right aortic sinus
   c. The right conus artery if it arises from the left anterior descending artery
   d. The right conus artery if it arises from the left coronary artery

4. The middle cardiac vein ends in:
   a. The great cardiac vein
   b. The small cardiac vein
   c. The coronary sinus
   d. The superior vena cava

5. The left brachiocephalic vein:
   a. Is a continuation of the left subclavian vein
   b. Is formed by union of left subclavian and left internal jugular veins
   c. Is formed by union of left subclavian and left external jugular veins
   d. Is formed by union of left external jugular and left internal jugular veins

ANSWERS

1. b **2.** d **3.** b **4.** c **5.** b

Clinical Problem-solving

Case Study 1: A 22-year-old man presents the following features: his radial pulse is normal, his blood pressure if recorded in the upper limb is increased, his blood pressure if recorded in the lower limb is very low and a skiagram shows rib notching.

- What condition is he affected from?
- Why is his blood pressure showing differences? Is he likely to have radiofemoral delay?
- What is the reason for rib notching?

Case Study 2: A 54-year-old man told you that he underwent 'bypass' surgery.

- Where do you think, does he have any disease/problem?
- What is the technical definition for 'bypass'?
- What other procedure could be tried in such a condition?

(For solutions see Appendix).

Chapter 9

Lymphatics of Thorax

Frequently Asked Questions

- Discuss the thoracic duct in detail.
- Write short notes on: (a) Lymph nodes in relation to thoracic wall, (b) Lymphatic drainage of diaphragm, (c) Lymphatic drainage of lungs.

The most important of the features of the thoracic lymphatics is the presence of the thoracic duct.

THORACIC DUCT

The thoracic duct is an elongated common lymphatic trunk which conveys chyle and most of the lymph of the body to the blood stream and extends from the second lumbar vertebra to the base of the neck. It is beaded in appearance which is due to the numerous valves present in it. It is the largest lymph vessel in the body and is about 40 cm long.

Course

The thoracic duct begins in the abdomen as the upward continuation of the confluence of lymph trunks which when present as a sac is called the ***cisterna chyli (Greek. chylos=juice)***. It enters the thorax by passing through the ***aortic opening*** of the diaphragm at the level of T12 vertebra. Within the opening, it lies to the right of the aorta and the left of the azygos vein. Once into the thorax, the thoracic duct ascends within the ***posterior mediastinum*** between the descending thoracic aorta and the azygos vein up to the fifth thoracic vertebra. Here, the vertebral column and terminal segments of the hemiazygos veins are posterior to it and the diaphragm and oesophagus are anterior.

At the level of the T5 vertebra, it inclines towards the left side, enters the ***superior mediastinum***, and ascends to the thoracic inlet along the left border of the oesophagus passing deep to the arch of aorta and the initial segment of the left subclavian artery.

At the root of neck, the thoracic duct arches laterally behind the carotid sheath containing the common carotid artery, the internal jugular vein and the vagus nerve at the level of the transverse process of the seventh cervical vertebra. Here, it is anterior to the vertebral vessels, left sympathetic trunk, left thyrocervical trunk, left phrenic nerve and the medial margin of the scalenus anterior.

The terminal part of the duct descends in front of the first part of the subclavian artery and ends by opening into the junction of the left subclavian vein and the internal jugular vein (Fig. 9.1). At its termination, it is guarded by a pair of valves to prevent regurgitation of blood into the duct.

Area of Drainage

Thoracic duct drains the lymphatics from both sides of the body below the diaphragm and from the left side above the diaphragm. In other words, it carries lymph from both lower limbs, pelvis, abdomen, left half of thorax, left half of head and neck and left upper limb (Fig. 9.2).

Tributaries of Thoracic Duct

The tributaries of the thoracic duct are:

- A pair of descending lymph trunks draining the posterior intercostal lymph nodes of lower six intercostal spaces;
- A pair of ascending lymph trunks draining the upper lumbar lymph nodes;
- Lymph vessels draining the posterior mediastinal and posterior intercostal lymph nodes of upper six spaces of the left side and
- ***Left subclavian trunk*** from the left upper limb and left ***jugular trunk*** from the left half of head and neck (received near its termination).

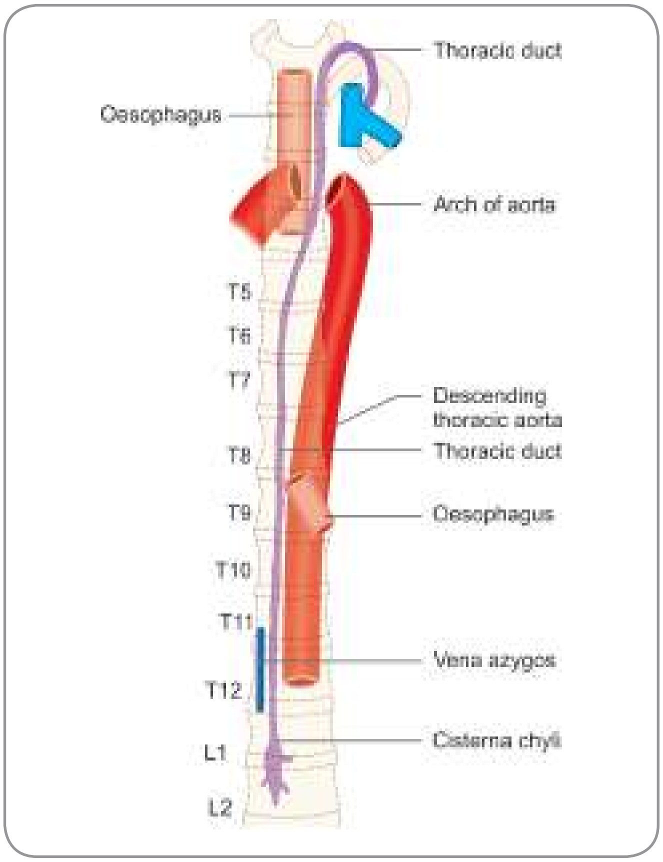


Fig. 9.1: Course and relations of thoracic duct as seen from the front

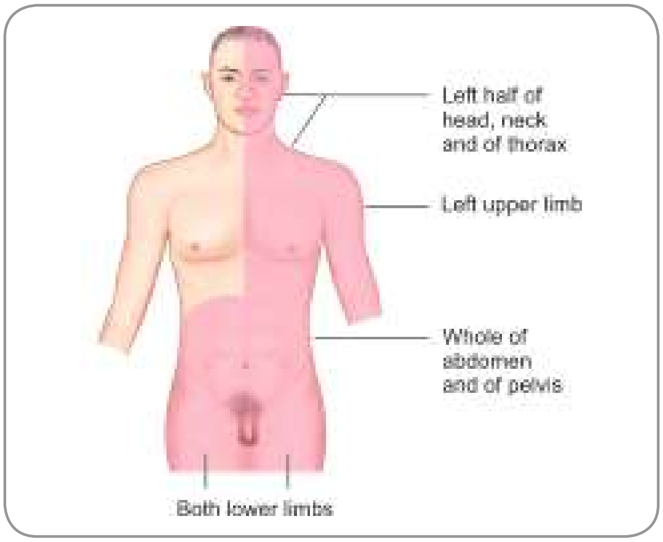


Fig. 9.2: Scheme to show the area of the body draining through the thoracic duct

The thoracic duct may also receive the ***left bronchomediastinal trunk*** from the upper part of thorax, but this trunk usually enters the subclavian vein independently (Fig. 9.3).

Clinical Correlation

- Thoracic duct may be obstructed by the growth of mature filarial parasites, sometimes causing bursting of lymph vessels. The condition is manifested by the collection of chylous fluid in the pleural and peritoneal sacs, chylous hydrocoele and chylous urine.
- Thoracic duct is vulnerable to damage after thoracic, particularly oesophageal surgery; the injury is life threatening if the duct is lacerated.

Right Bronchomediastinal Trunk

Lymph from the right half of thorax is drained by the right bronchomediastinal lymph trunk. This trunk also

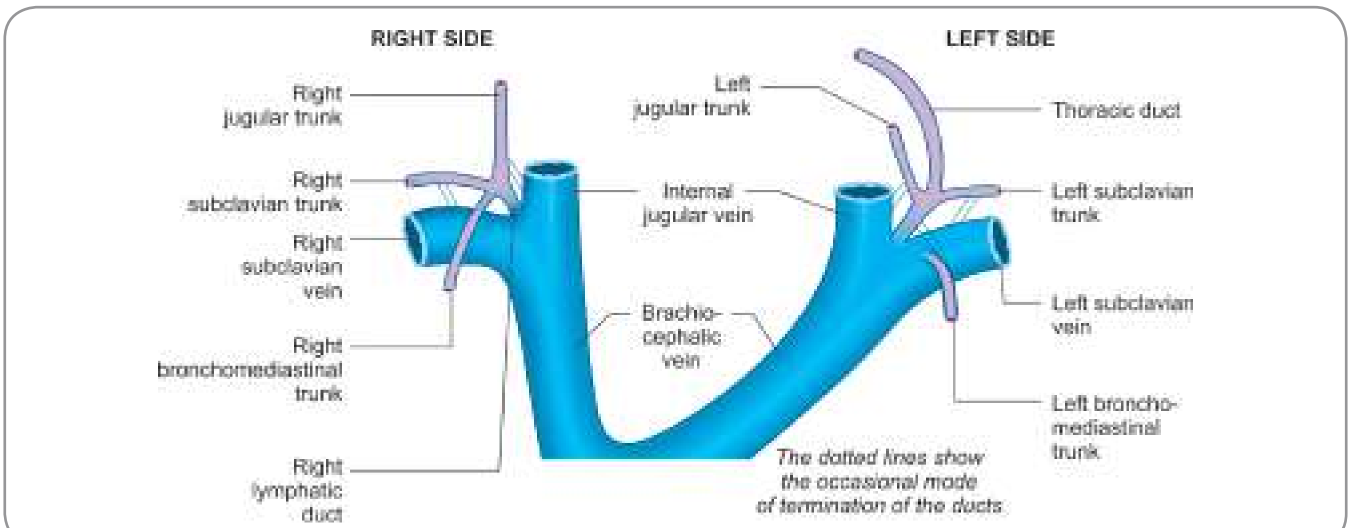


Fig. 9.3: Scheme to show the main lymphatic ducts

drains lymph from the convex upper surface of the liver. It ascends into the neck where it joins the ***right jugular trunk*** from the right half of head and neck and the ***right subclavian trunk*** from the right upper limb to form the ***right lymphatic duct***. The position, course and relations of the right lymphatic duct correspond to those of the terminal part of the thoracic duct (on the left side).

LYMPH NODES OF THORAX

The lymph nodes of thorax can be divided into those present in relation to the thoracic wall and those present in relation to the contents of thorax (Fig. 9.4).

Nodes Present in Relation to Thoracic Wall

The following are the nodes present in relation to the thoracic wall:

- The ***parasternal*** nodes which lie at the anterior ends of the intercostal spaces, along the course of the internal thoracic artery lateral to the sternum;
- The ***intercostal*** lymph nodes which lie at the posterior ends of the intercostal spaces and
- The ***diaphragmatic*** lymph nodes which lie on the thoracic surface of the diaphragm.

  The diaphragmatic nodes consist of the following subgroups:
  - The ***anterior group*** behind the xiphoid process;
  - The right and left ***lateral groups*** near the points where the corresponding phrenic nerves pierce the diaphragm and
  - The ***posterior group*** behind the crura of the diaphragm.

Nodes Present in Relation to Contents of Thorax

The following are the nodes present in relation to the contents of thorax:

- The ***brachiocephalic*** lymph nodes which lie in the superior mediastinum, in front of the brachiocephalic veins (Fig. 9.4);
- The ***posterior mediastinal*** lymph nodes present in relation to the oesophagus and the descending thoracic aorta and
- The ***tracheobronchial*** lymph nodes (Fig. 9.5) along the trachea and bronchi. The tracheobronchial nodes consist of the following subgroups:
  - The ***paratracheal nodes*** on either side of the trachea;
  - The ***superior tracheobronchial*** nodes in the angle between the trachea and the principal bronchi;
  - The ***inferior tracheobronchial*** nodes below the bifurcation of trachea;
  - The ***bronchopulmonary*** nodes at the hilum of the right and left lungs and
  - The ***pulmonary*** nodes along the bronchi within the substance of the lungs.

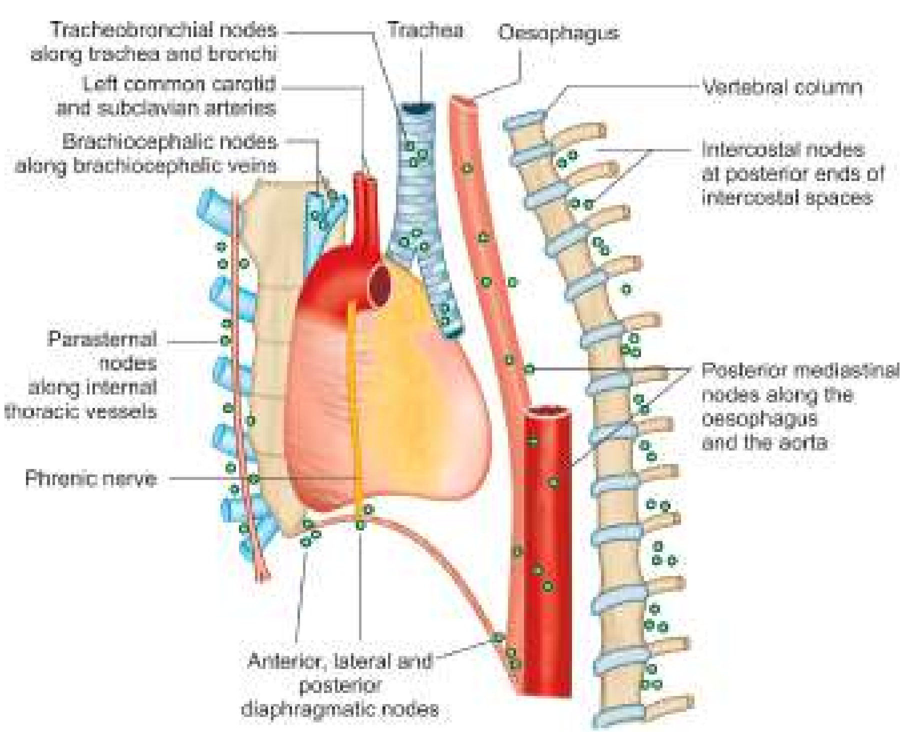


Fig. 9.4: Scheme to show the lymph nodes of thorax

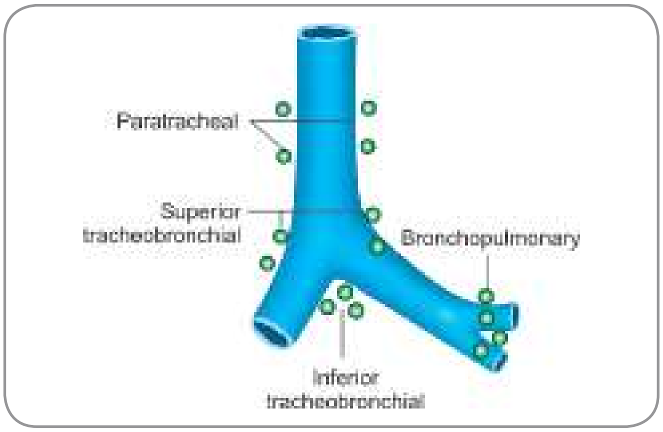


Fig. 9.5: Tracheobronchial lymph nodes

Lymphatic Drainage of Thoracic Wall

The skin overlying the thorax drains mainly into the ***axillary lymph nodes***. The vessels from the back of the thorax drain into the ***posterior group***, while those from the front drain into the ***anterior group***. The skin near the sternum drains into the ***parasternal nodes*** (Fig. 9.6).

The deeper tissues including the muscles covering the chest wall and the costal pleura drain anteriorly into the parasternal nodes and posteriorly into the intercostal nodes.

Efferents from the ***parasternal nodes*** along with those from the tracheobronchial and brachiocephalic nodes form the ***bronchomediastinal lymph trunk***. On the left side, this trunk may join the thoracic duct, but it usually opens into the subclavian vein independently. On the right side, the bronchomediastinal trunk joins the right lymphatic duct.

Efferents from both the ***upper and lower intercostal nodes*** of the left side end in the thoracic duct. Also, efferents from the intercostal nodes in the lower six spaces of the right side end in the thoracic duct, but efferents of the upper nodes reach the right bronchomediastinal trunk (Fig. 9.7).

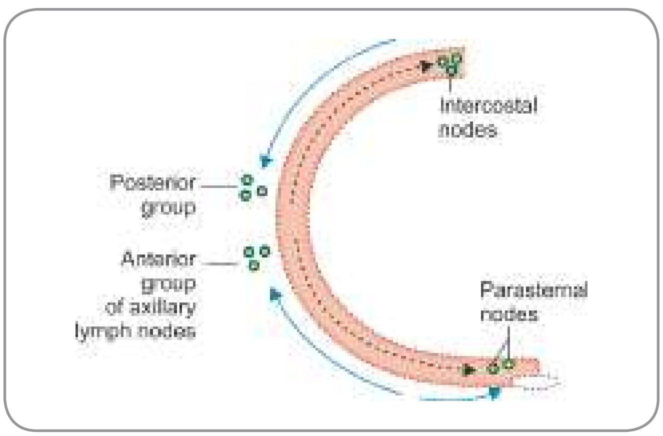


Fig. 9.6: Scheme to show lymphatic drainage of skin and deeper tissues of thoracic wall

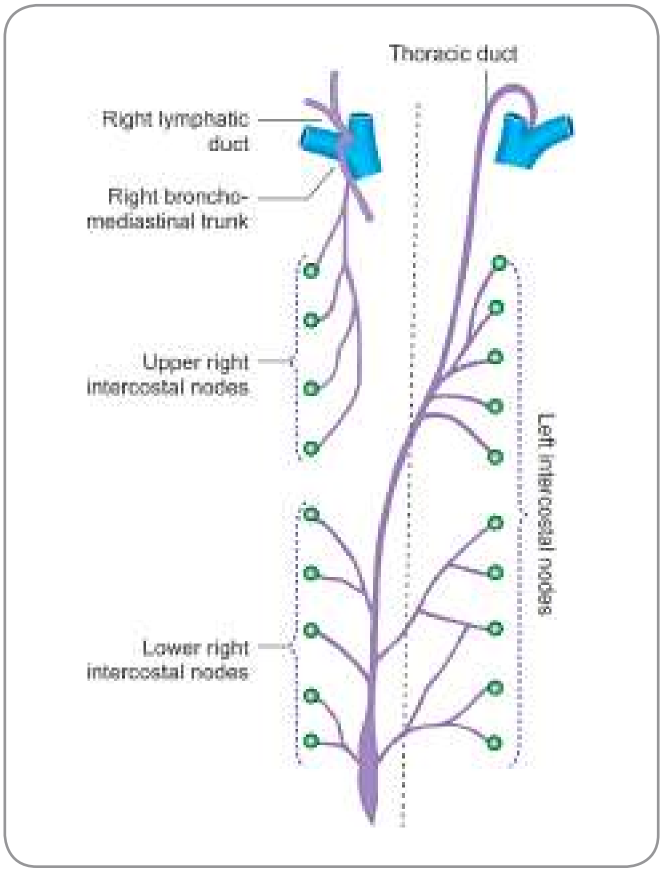


Fig. 9.7: Scheme to show efferent vessels arising from intercostal lymph nodes

Lymphatic Drainage of Diaphragm (Fig. 9.8)

The ***diaphragm*** is drained by separate sets of lymph vessels on its thoracic and abdominal surfaces.

- The ***thoracic surface*** is drained as follows:
  - Lymph vessels from the anterior part drain into the anterior diaphragmatic nodes and through them to the parasternal nodes;
  - Lymph vessels from the middle part drain into the right and left lateral diaphragmatic nodes and from there to the parasternal nodes and nodes around the oesophagus (part of the posterior mediastinal group);
  - Lymph vessels from the posterior part drain into the posterior diaphragmatic nodes and through them to nodes around the lower end of the thoracic aorta.
- The ***abdominal surface*** of the diaphragm drains into the lymph nodes of abdomen. The right and left halves of the diaphragm are drained by separate sets of vessels.
  - On the right side, the vessels end in ***nodes lying along the inferior phrenic artery***, and in the ***lateral aortic nodes*** present along the right side of abdominal aorta.
  - On the left side, the lymph vessels end in the ***preaortic nodes*** (in front of the aorta) and in nodes around the lower end of oesophagus.

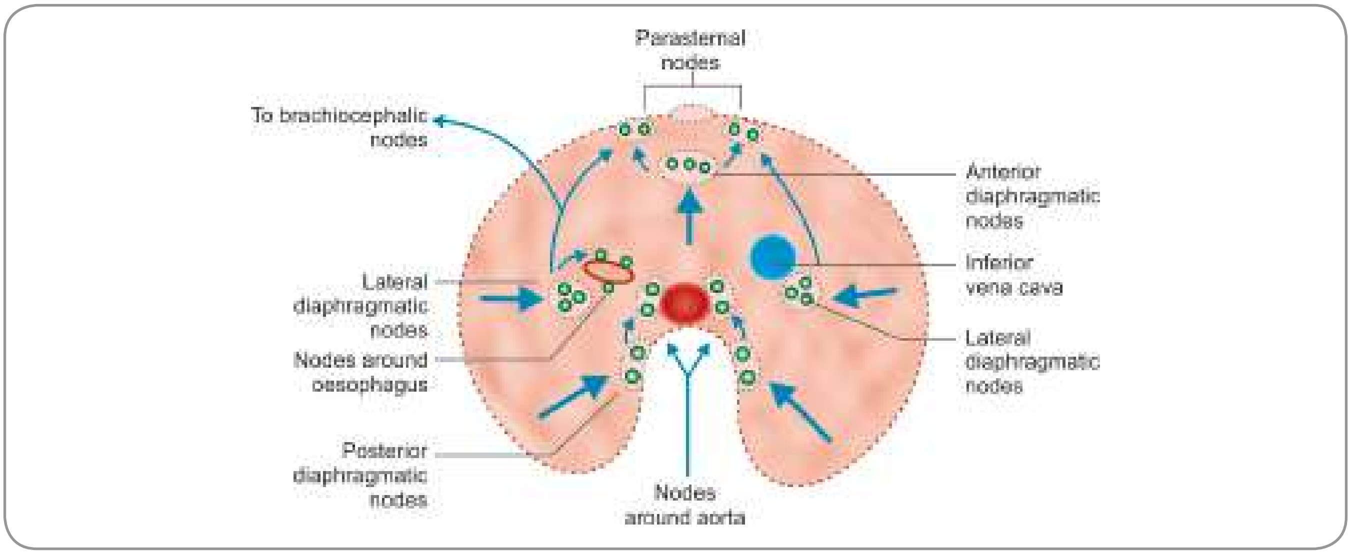


Fig. 9.8: Scheme to show lymphatic drainage of thoracic surface of diaphragm

Lymphatic Drainage of Thoracic Viscera (Fig. 9.9)

Lymphatic Drainage of Trachea (Fig. 9.10)

The ***cervical part*** of the trachea drains into the ***deep cervical nodes*** directly and also through the ***pretracheal*** and ***paratracheal*** nodes. The ***thoracic part*** of the trachea drains into the right and left superior tracheobronchial nodes and into the inferior tracheobronchial nodes.

Lymphatic Drainage of Lungs (Fig. 9.11)

Two sets of lymphatic plexuses drain the lungs and pleurae. Both the plexuses communicate freely.

The ***superficial plexus*** lies deep to the visceral pleura and thus drains the lung parenchyma and the visceral pleura. It is called the ***subpleural lymphatic plexus***; the lymphatic vessels which start from this plexus drain into the bronchopulmonary nodes at the hilum.

The ***deep plexus*** lies in the submucosa of the bronchi and in the peribronchial connective tissue. It drains the structures which form the root of the lung. The lymphatic vessels which arise from this plexus drain first into the pulmonary lymph nodes which are located along the lobar bronchi. The efferents from the pulmonary nodes follow the bronchi, reach the hilum and drain into the bronchopulmonary lymph nodes.

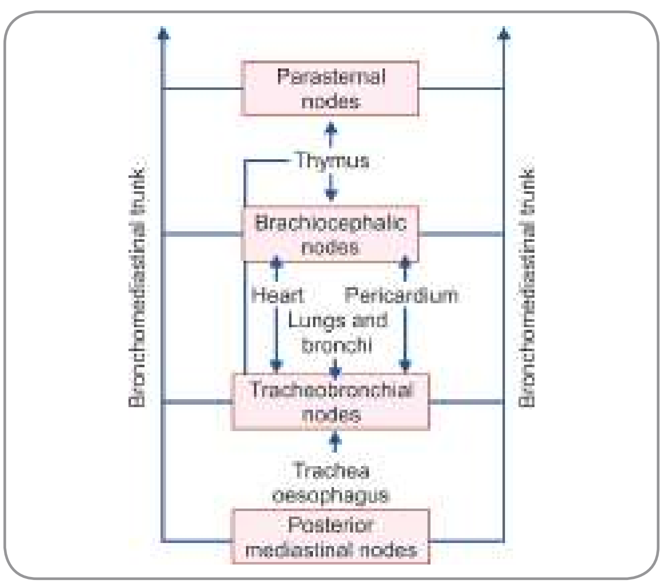


Fig. 9.9: Scheme to show interconnections of major lymph nodes draining the thoracic viscera

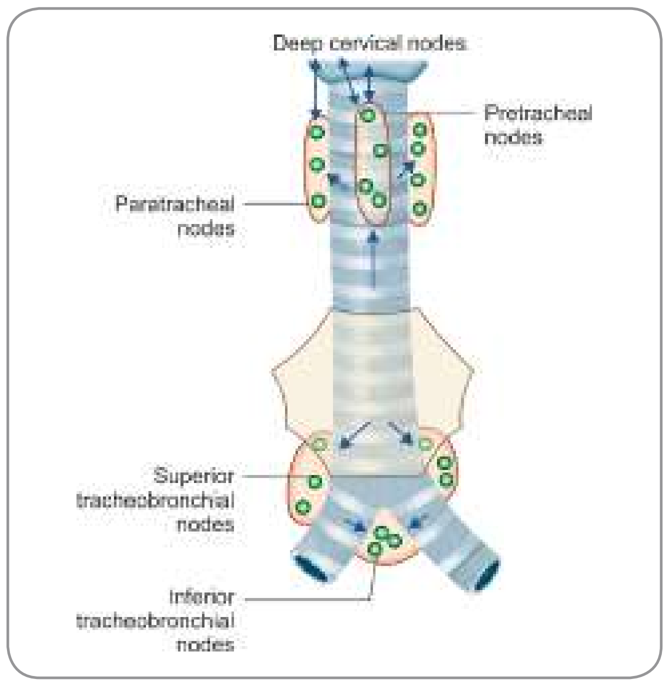


Fig. 9.10: Lymphatic drainage of trachea

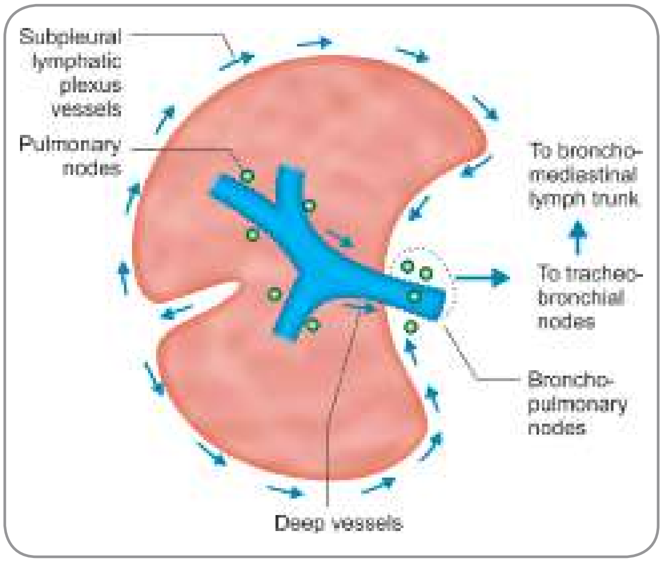


Fig. 9.11: Lymphatic drainage of lungs

Efferents from the bronchopulmonary nodes reach the superior and inferior tracheobronchial lymph nodes which lie superior and inferior to the bifurcation of the trachea. Lymph from the tracheobronchial nodes go through the right and left bronchomediastinal lymph trunks which join the venous stream either directly or through the right lymphatic and thoracic ducts. Lymph vessels are conspicuously absent around the alveolar walls as the air may be sucked into the lymph vessels and thence into the blood.

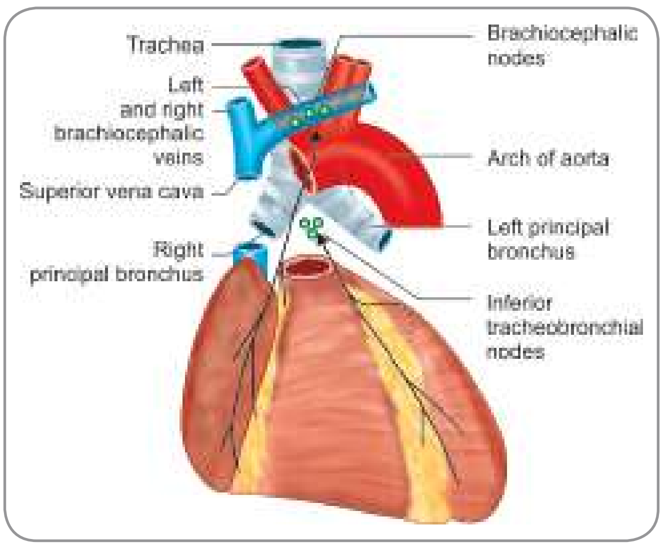


Fig. 9.12: Scheme to show the lymphatic drainage of heart

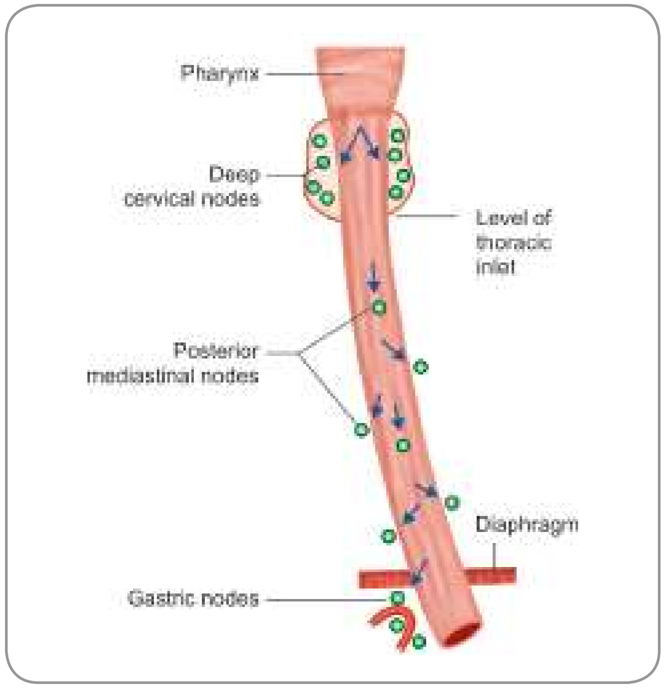


Fig. 9.13: Lymphatic drainage of oesophagus

Lymphatic Drainage of Heart (Fig. 9.12)

The heart is drained through vessels which travel mainly in the interventricular and atrioventricular grooves (Fig. 9.12). One set runs in the anterior part of the atrioventricular groove. The vessels of this set cross the aorta to reach the brachiocephalic nodes. Another set of vessels runs along the anterior interventricular groove and ends in the inferior tracheobronchial nodes.

Lymphatic Drainage of Oesophagus (Fig. 9.13)

The cervical part of oesophagus drains into the deep cervical lymph nodes. The thoracic part drains into the posterior mediastinal lymph nodes. The abdominal part of oesophagus drains into the left gastric lymph nodes.

Multiple Choice Questions

1. The thoracic duct enters the thorax through the:
   a. Aortic opening of diaphragm
   b. Oesophageal opening of diaphragm
   c. The right crus of diaphragm
   d. Venacaval opening of diaphragm
2. The diaphragmatic lymph nodes have the:
   a. Anterior, posterior and medial groups
   b. Medial, lateral and posterior groups
   c. Medial, lateral and anterior groups
   d. Anterior, posterior and lateral groups
3. The superficial lymphatic plexus of the lungs is otherwise called the:
   a. Subvisceral plexus
   b. Parenchymal plexus
   c. Subliminal plexus
   d. Subpleural plexus
4. The termination of thoracic duct has valves:
   a. To channelise flow of lymph
   b. To contract and let lymph periodically out
   c. To prevent regurgitation of blood
   d. With no function

ANSWERS

1. a **2.** d **3.** d **4.** c

Clinical Problem-solving

Case Study 1: You are studying microslides of lung tissue under very high magnification. You do notice that there are no lymph vessels near the alveolar walls.

- Can you correlate your anatomy knowledge with clinical applications with regard to this histological fact?

(For solutions see Appendix).

Chapter **10**

Nerves of Thorax (Including an Introduction to the Autonomic Nervous System)

Frequently Asked Questions

- Write in detail about the phrenic nerve and its distribution.
- Write notes on: (a) Recurrent laryngeal nerve, (b) Cardiac plexuses, (c) Thoracic part of sympathetic trunk

The nerves of thorax belong to two distinct functional categories—the spinal nerves and autonomic nerves.

- Branches of ***spinal nerves*** supply mainly the skeletal muscles and skin. In the thorax, the nerves belonging to this category are the ***intercostal, subcostal and phrenic nerves.***
- ***Autonomic nerves*** supply the ***viscera***, including the smooth muscles in the walls of blood vessels and glands.

Both spinal and autonomic nerves carry motor (or efferent) and sensory (or afferent) fibres.

SPINAL NERVES OF THORAX

The skin, fasciae and skeletal muscles of thorax are supplied by spinal nerves. The intercostal and subcostal nerves which belong to this group have been discussed in detail in the chapter on Walls of Thorax.

Phrenic Nerve

The phrenic nerves are a pair of mixed peripheral nerves which provide the sole motor supply to the diaphragm. Each phrenic nerve arises from the anterior primary rami of C3, C4 and C5 spinal nerves. The contribution from C4 is the greatest.

Course

The phrenic nerve is formed in the neck in the upper part of lateral border of scalenus anterior muscle. It descends vertically through the lower part of the neck and then through the thorax to reach the diaphragm. Some terminal branches enter the abdomen.

In the neck, the phrenic nerve descends vertically across the scalenus anterior muscle, crosses the medial border of the muscle, and then the front of the first part of the subclavian artery. On the right side, however, the nerve is usually separated from the artery by a part of the scalenus anterior. Throughout its course in the neck, the nerve lies deep to the sternocleidomastoid muscle.

On entering the thorax, the nerve passes medially, crosses in front of the internal thoracic artery and then traverses the superior mediastinum and the middle mediastinum. In the middle mediastinum, the nerve is accompanied by pericardiacophrenic vessels. The course of the phrenic nerves on the right and left sides are different in the thorax.

- ***Course of the left phrenic nerve in the thorax:*** Above the arch of aorta, the nerve lies in the interval between the left common carotid and left subclavian arteries. It, at first lies posterior and lateral to the vagus nerve, but crosses the latter superficially and comes to lie in front and medial to it. Just above the arch of aorta, the left brachiocephalic vein crosses these structures.
  The nerve then crosses the arch of aorta lying on the latter's anterolateral side. Here, the nerve crosses superficial to the left superior intercostal vein. Below the arch of aorta, the phrenic nerve crosses in front of the structures comprising the root of left lung and then descends across the left ventricle of the heart lying between the parietal pericardium and the mediastinal pleura.
- ***Course of the right phrenic nerve in the thorax:*** After crossing the internal thoracic artery, the nerve reaches near the right brachiocephalic vein. It runs downwards lateral to this vein; at the lower end of the vein, the

nerve passes onto the lateral side of the superior vena cava. Leaving the vena cava, the nerve descends over the right side of the heart (right atrium) lying between the parietal pericardium and the mediastinal pleura. Just above the diaphragm, the nerve lies lateral to the inferior vena cava.

The ***relationship of both the phrenic nerves to the diaphragm*** is as follows:

- The nerves pierce the diaphragm and divide into branches which ramify within the substance of the muscle or on the ***inferior*** surface of the muscle.
- The right phrenic nerve passes through the opening for the inferior vena cava, or pierces the central tendon just lateral to this opening.
- The left phrenic nerve pierces the muscular part of the diaphragm in front of the central tendon.

Area of Supply of Phrenic Nerves

The portion of the diaphragm including the right crus on the right side of the oesophageal opening is supplied by the right phrenic nerve; rest of the diaphragm on the left side of that opening is supplied by the left phrenic nerve. Therefore the right crus is supplied by both the phrenic nerves, whereas the left crus is supplied by the left phrenic nerve only.

Apart from motor fibres to the diaphragm, each phrenic nerve also carries a number of sensory fibres.

- It carries proprioceptive fibres from the diaphragm.
- In the thorax, it gives off sensory branches to the pericardium and the parietal pleura.
- The nerve also carries sensations from some organs/ structures within the abdomen including the suprarenal glands, the inferior vena cava and the gallbladder.

Accessory Phrenic Nerve

The root of the phrenic nerve from C5 may sometimes follow a complicated course. Instead of arising from C5 itself, it may arise from the nerve to the subclavius. From here, the root descends through the neck lateral to the main phrenic nerve and joins it in the upper part of thorax. Such a root from C5 constitutes the accessory phrenic nerve.

Clinical Correlation

- Irritation of the central part of diaphragm due to inflammation of the diaphragmatic pleura or peritoneum may be referred to the tip of the shoulder and the lower part of neck along the distribution of the supra clavicular nerves (C3 and C4) (referred pain due to common or shared origin of nerve fibres).
- Sometimes, crushing of the phrenic nerve at the root of neck is done to immobilise the corresponding half of diaphragm in certain diseases of the lung (to restrict respiratory mobility).

AUTONOMIC NERVES OF THORAX

The autonomic nerves of the thorax include the ***sympathetic trunks*** and the ***two vagal nerves***.

Preliminary Remarks on the Autonomic Nervous System

It is necessary to know certain general principles before a study of the autonomic nerves of thorax is undertaken.

The autonomic nervous system is responsible for the nerve supply of viscera and blood vessels. It is subdivided into two main parts. These are the ***sympathetic*** and ***parasympathetic*** nervous systems. Both these divisions contain efferent as well as afferent fibres. The efferent fibres supply smooth muscles throughout the body. The influence of these nerves may be either to cause contraction or relaxation. In addition to the supply of smooth muscles, autonomic nerves supply glands also. Such nerves are described as ***secretomotor***. The secretomotor supply to almost all glands is parasympathetic, the only exception being that to the sweat glands which is sympathetic.

In the thorax, the ***parasympathetic nervous system*** is represented by the ***vagus nerve*** and the ***sympathetic nervous system*** by the right and left ***sympathetic trunks*** and their branches.

Basic Arrangement of Efferent Autonomic Pathways

- The pathway for supply of a smooth muscle or a gland (Fig. 10.1) always consists of two neurons which synapse in a ganglion in both the sympathetic and parasympathetic pathways.
- The cell body of the first or ***preganglionic*** neuron (pre=before; the term 'ganglionic' because synapse usually occurs in a group of neurons; current trend is to replace the terms 'preganglionic' and 'postganglionic' with the terms 'presynaptic' and 'postsynaptic' respectively) is located within the brain or spinal cord.

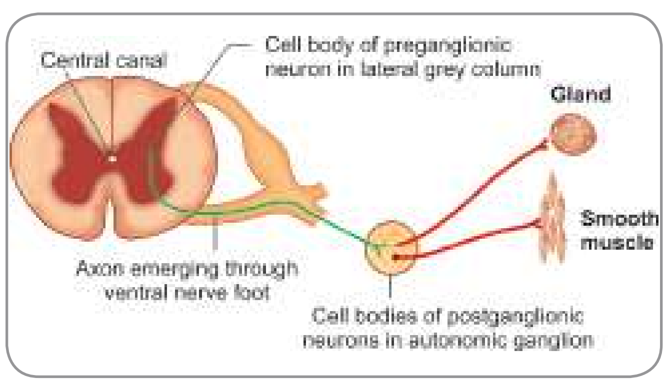


Fig. 10.1: Scheme to show arrangement of nerve pathways supplying smooth muscle or gland

Its axon enters a peripheral nerve and after a variable course ends in a ganglion.

- The cell body of the second, or ***postganglionic***, neuron is located in the ganglion. Its axon reaches the smooth muscle or gland and supplies it (Fig. 10.1).

Autonomic Plexuses

Autonomic fibres, both sympathetic and parasympathetic, reach the thoracic and abdominal viscera through a number of plexuses present around the arteries of the region. Although they are called ***plexuses***, they contain numerous neurons and are in fact equivalent to ganglia. Most of the sympathetic fibres passing through them are postganglionic (having relayed in ganglia within the sympathetic trunk). Some are preganglionic and relay in the plexuses. Parasympathetic fibres reaching the plexuses through the vagus are entirely preganglionic. Some of them pass through the plexuses without relay and reach the concerned viscera. They then relay in the ganglia (or plexuses) present within the viscera. Many of them synapse in the plexuses.

The autonomic plexuses seen in the thorax are as follows:

- Cardiac plexuses
  - Superficial cardiac plexus
  - Deep cardiac plexus.
- Pulmonary plexuses
  - Anterior pulmonary plexus
  - Posterior pulmonary plexus.
- Oesophageal plexuses
  - Anterior oesophageal plexus
  - Posterior oesophageal plexus.

Arrangement of Parasympathetic Pathways

The parasympathetic nervous system consists of a ***cranial*** part and a ***sacral*** part.

Preganglionic neurons of the ***cranial part*** are located in the brainstem (general visceral efferent nuclei of the cranial nerves). Details of these will be considered in the section on the head and neck.

- The preganglionic fibres arising from them pass through the third, seventh, ninth and tenth cranial nerves. They collectively constitute the ***cranial parasympathetic outflow***.
- The only fibres of this outflow relevant to the thorax and abdomen are those that travel through the vagus nerve (tenth cranial nerve).

Postganglionic neurons of the ***cranial part*** of the parasympathetic nervous system are located in a number of ganglia present in association with branches of the cranial nerves concerned. Usually the ganglia of the parasympathetic system lie very close to or within the substance of the organ that it supplies. Postganglionic neurons related to the vagus nerve are scattered in the autonomic plexuses.

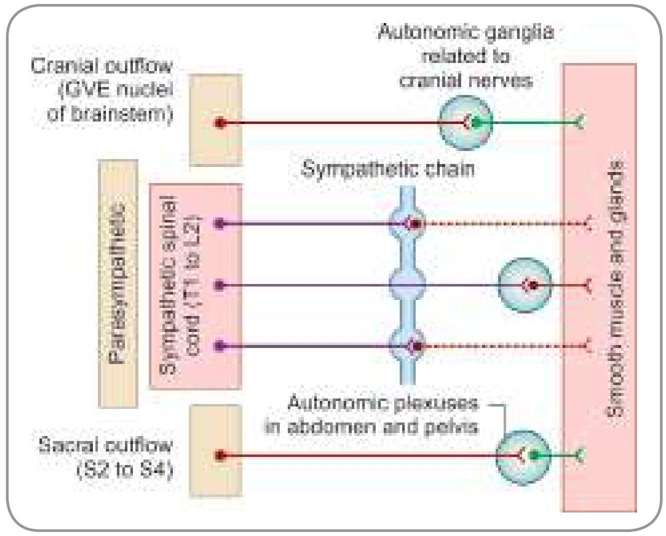


Fig. 10.2: Basic plan of the sympathetic and parasympathetic nervous systems

Preganglionic neurons of the ***sacral part*** of the parasympathetic nervous system are located in the sacral segments of the spinal cord (intermedio-lateral grey column in spinal segments S2, S3 and S4).

- Their axons constitute the ***sacral parasympathetic outflow*** (Fig. 10.2).
- They are concerned with the innervation of some viscera in the abdomen and pelvis.

Post ganglionic neurons are very short and are located within the plexuses.

VAGUS NERVE

The vagus or the tenth cranial nerve arises from the medulla oblongata of the brain, passes through the head and neck, thorax and abdomen, and has an extensive distribution. It acts as the chief pathway of the cranial part of the parasympathetic system and supplies the derivatives of foregut and midgut. Each nerve consists of three parts—***cervical, thoracic*** and ***abdominal*** (In this section the thoracic part of the vagus nerve is detailed).

The vagus nerve exits the cranial cavity through the jugular foramen in association with the ninth and eleventh cranial nerves and then descends vertically in the neck in close relationship to the internal and the common carotid arteries and the internal jugular vein. In the lower part of the neck, the nerve crosses anterior to the first part of the subclavian artery (Fig. 10.3) and enters the thorax.

Course and Relations of Vagus Nerve in Thorax (Fig. 10.3)

Thoracic course of the vagus nerves differs in the right and the left sides.

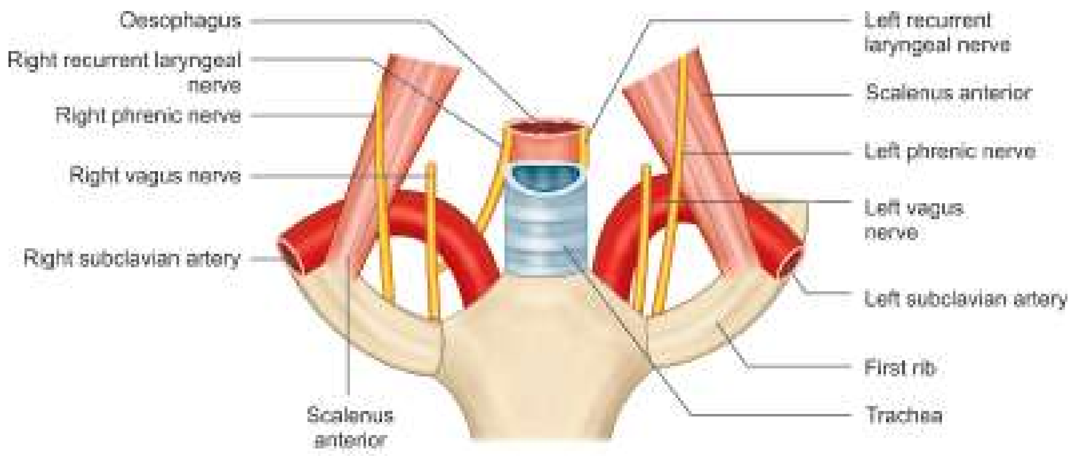


Fig. 10.3: Relationship of subclavian artery to the vagus nerve. The phrenic nerve is also shown

Right Vagus Nerve

In the superior mediastinum, nerve passes posteromedial to the brachiocephalic vein, lies on the right of trachea and then descends posteromedial to the superior vena cava. Above the lung root, the vagus is separated from the right lung and pleura by the arch of the azygos vein. Thereafter, the nerve passes behind the lung root, where it breaks down into branches and joins with the sympathetic fibres to form the pulmonary plexus. Below the lung root, the fibres of the right vagus nerve surround the oesophagus and form the ***posterior oesophageal plexus***. Finally, the fibres enter the abdomen through the oesophageal opening of the diaphragm as the ***posterior vagal trunk***.

Left Vagus Nerve

In the superior mediastinum, the left vagus nerve descends between the left common carotid and the left subclavian arteries, behind the left brachiocephalic vein and then crosses the left side of the arch of aorta to reach the posterior aspect of the root of left lung. Above the arch of aorta, the vagus is crossed by the left phrenic nerve. Over the arch of aorta, it is crossed by the left superior intercostal vein. The nerve is related laterally to the left lung and pleura. Thereafter the nerve passes behind the lung root, where it breaks down into branches and joins with the sympathetic fibres to form the pulmonary plexus like the right vagus nerve. Below the lung root, the fibres of the left vagus nerve surround the oesophagus and form the ***anterior oesophageal plexus***. Finally the fibres enter the abdomen through the oesophageal opening of the diaphragm as the ***anterior vagal trunk***.

Branches of the Vagus Nerve in Thorax

Left Recurrent Laryngeal Nerve

The left recurrent laryngeal nerve arises from the left vagus in the thorax, as the latter crosses lateral to the arch of aorta. The nerve hooks below the arch of aorta immediately behind the ligamentum arteriosum and then passes upwards and medially deep to the arch of aorta to reach the side of the trachea. It then ascends in the groove between the trachea and the oesophagus to reach the larynx.

Right Recurrent Laryngeal Nerve

The right recurrent laryngeal nerve is a branch of the vagus nerve but given out in the neck. It is confined to the neck and does not enter the thorax. It arises from the vagus as the latter passes in front of the subclavian artery in the root of the neck. It then passes backwards below the artery and then upwards behind the artery forming a loop. The nerve then runs upwards and medially to reach the side of the trachea (Fig. 10.4).

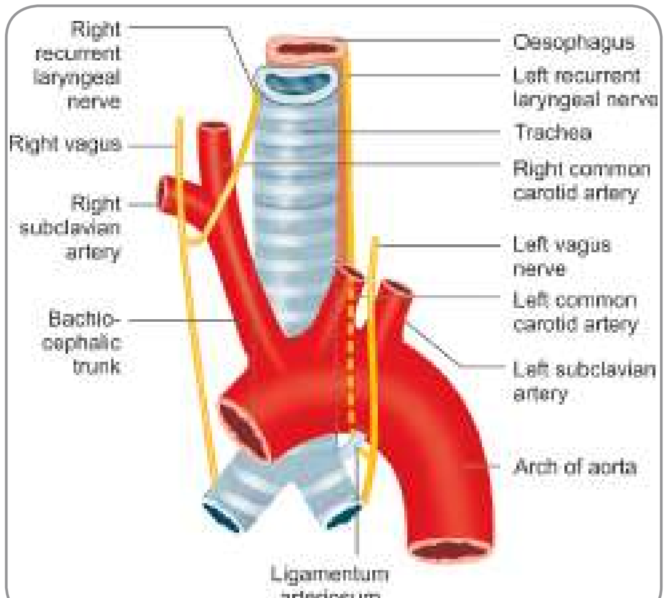


Fig. 10.4: Course of recurrent laryngeal nerves on the right and left sides

The difference in the site of origin of the right and left recurrent laryngeal nerves is related to the development of the aortic arches in the foetus.

The recurrent laryngeal nerves provide the motor supply to most of the intrinsic muscles of the larynx. The nerves also provide the sensory supply to the mucous membrane of the lower half of the larynx. They also give sensory branches to the trachea and the oesophagus. Some branches are given off to the deep cardiac plexus.

Cardiac Branches and Cardiac Plexuses

While descending through the neck, each vagus nerve gives off one or more superior cervical cardiac branches and an inferior cervical cardiac branch. These branches descend into the thorax and take part in the formation of the cardiac plexuses. Additional cardiac branches arise from the vagus nerve in the superior mediastinum and also from the recurrent laryngeal branches.

The ***superficial cardiac plexus*** is located just below the arch of aorta, close to the ligamentum arteriosum. It is formed by the inferior cervical cardiac branch of the left vagus nerve and the cardiac branch from the superior cervical ganglion of the left sympathetic trunk.

The ***deep cardiac plexus*** is situated in front of the bifurcation of trachea. It receives several branches from the right and left vagus nerves as follows:

- Superior and inferior cervical cardiac branches of right vagus.
- Superior cervical cardiac branch of the left vagus.
- Branches from right and left vagi arising in the thorax.
- Branches from the right and left recurrent laryngeal nerves.
- Numerous cardiac branches from the right and left sympathetic trunks.

Branches from the superficial and deep cardiac plexuses supply the heart.

Pulmonary Branches and Pulmonary Plexus

On reaching the root of the lung, each vagus divides into a number of branches which form the corresponding right and left ***posterior pulmonary plexuses***. Each plexus also receives several branches from the sympathetic trunk. Some branches of the vagus reach the front of the root of lung and form a less prominent anterior pulmonary plexus. Branches from these plexuses accompany the bronchi and supply the smooth muscles in their wall.

Oesophageal Branches

Fibres of the right and left vagus nerves emerge from the posterior pulmonary plexuses and descend on the oesophagus forming the anterior and posterior oesophageal plexuses. Although both plexuses receive fibres from the nerves of both sides, the ***anterior oesophageal plexus*** is formed mainly by fibres from the ***left vagus*** and the ***posterior oesophageal plexus*** mainly by fibres from the ***right vagus***. Branches from these plexuses supply the oesophagus and the posterior part of the pericardium.

Arrangement of Sympathetic Pathways

The ganglia related to the sympathetic nerves are located mainly in the right or left sympathetic trunks. Each trunk is a long nerve cord placed on either side of the vertebral column and extends from the base of skull above, to the coccyx below. The sympathetic ganglia are seen as enlargements along the length of the trunk. Basically, there is one ganglion corresponding to each spinal nerve, but in many situations the ganglia of adjoining segments fuse so that they appear to be fewer in number than the spinal nerves.

The Sympathetic system comprises of both ***sensory*** and ***motor*** components.

Motor Component

The motor component includes both preganglionic and postganglionic neurons.

The cell bodies of sympathetic ***preganglionic neurons*** are located in the ***intermedio-lateral grey column*** of the spinal cord in spinal segments T1 to L2. Their axons leave the spinal cord through the ventral nerve root to enter the corresponding spinal nerve. After a very short course through the ventral primary ramus, these fibres pass into the ***white ramus communicans*** (Fig. 10.5) and reach the sympathetic ganglion (of the corresponding segmental level). The white ramus communicans is a delicate connecting channel between the ventral primary ramus of the peripheral nerve and the sympathetic ganglion situated in the sympathetic trunk. These preganglionic fibres leaving the spinal cord through spinal nerves T1 to L2 collectively form the ***thoracolumbar outflow.***

On reaching the sympathetic trunk, the ***preganglionic fibres*** (Fig. 10.5) terminate in one of the following ways:

- They may terminate (Fig. 10.6) in relation to the corresponding cells of the sympathetic ganglion;
- They may ascend or descend along the sympathetic trunk to synapse with ganglia at higher or lower levels in the trunk;
- They may leave the sympathetic trunk without synapsing as its medial or splanchnic branch to terminate in relation to neurons located along the aorta and its branches (these neurons being called the ***collateral ganglia***) or rarely within the terminal ganglion present in the target organ.

The branches of the sympathetic trunk are the thoracic and lumbar splanchnic nerves.

Sympathetic ***postganglionic neurons*** are located primarily in the ganglia of the sympathetic trunks. Some

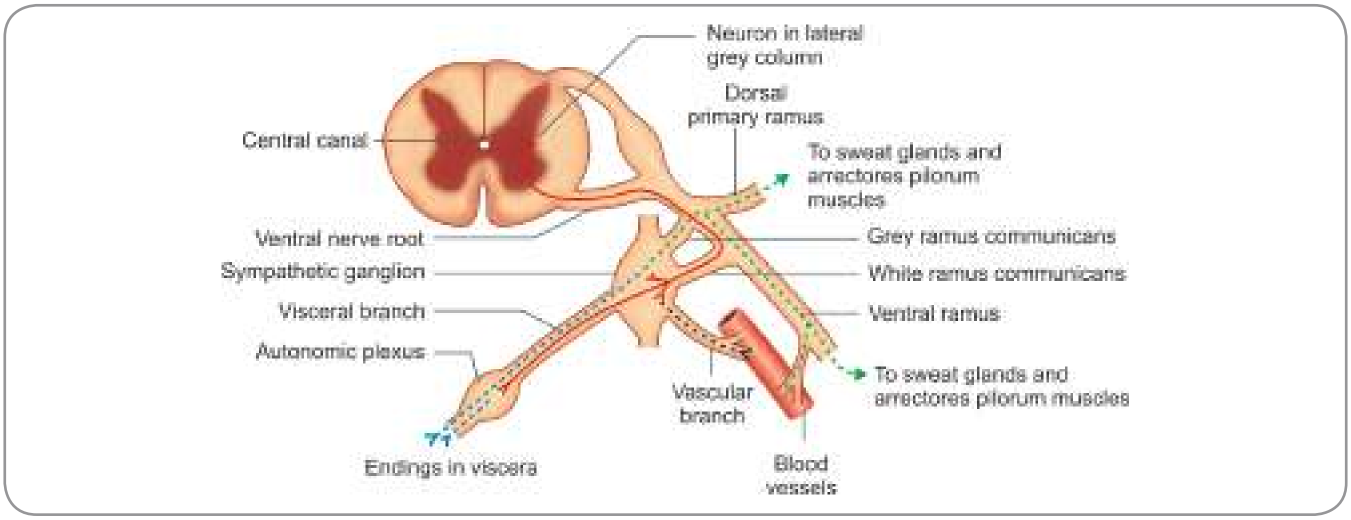


Fig. 10.5: Grey and white rami connecting a spinal nerve to the sympathetic trunk, and the fibres passing through them. Preganglionic fibres are shown in red line and postganglionic fibres in blue or green

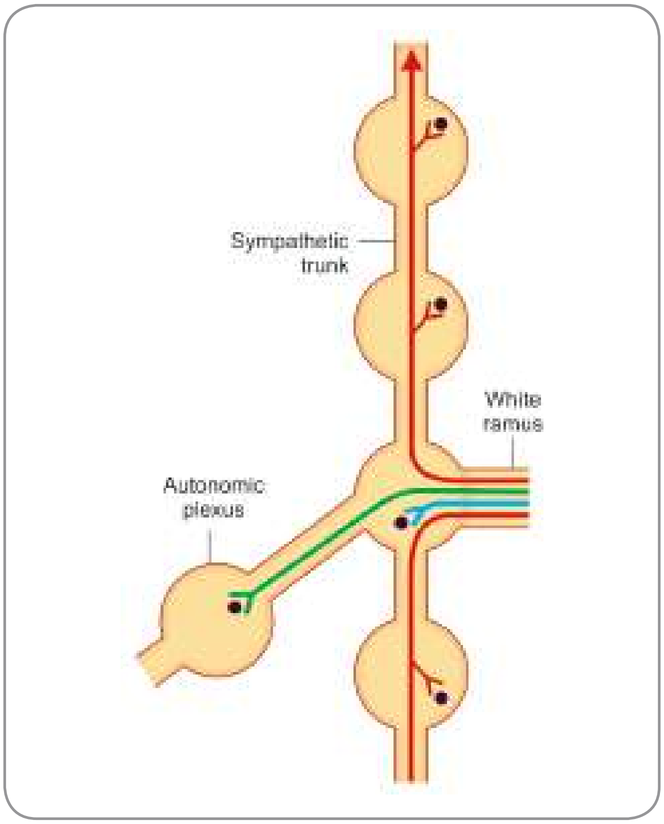


Fig. 10.6: Mode of termination of sympathetic preganglionic neurons

are located in the ganglia around the aorta and its branches (called the collateral ganglia) or rarely within the target organ (typical example being the supra renal medulla). Axons arising from them reach the effector organs in one of the following ways:

- The axons may pass through a grey ramus communicans, which is a connecting channel between the sympathetic ganglion and the ventral primary ramus, to reach a spinal nerve. They then pass through the ventral and the dorsal primary rami to innervate skin, blood vessels and hair in the region of distribution of the nerve (Fig. 10.7).
- The axons may pass into vascular branches which form plexuses over the vessels and their branches. Some fibres from these plexuses may pass to other structures in the neighbourhood of the vessels. Fibres meant for blood vessels may also reach them through spinal nerves or their branches.

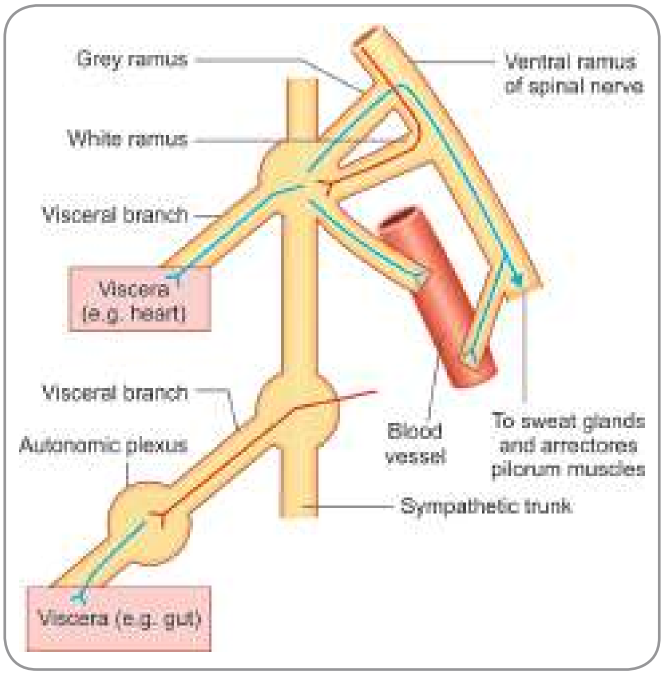


Fig. 10.7: Course and termination of sympathetic postganglionic neurons

- The axons of postganglionic neurons located in sympathetic ganglia may travel through splanchnic branches and through autonomic plexuses to reach some viscera (e.g., the heart).
- Some axons ascend or descend through the sympathetic trunk and reach wide areas of distribution via the grey rami communicantes or the splanchnic branches.

One preganglionic neuron makes synapses with 20 or more postganglionic neurons. Therefore, the actions of sympathetic system are widespread and mobilise resources in cases of emergency, popularly called the ***flight, fright and fight response***.

Sensory Component

This component of sympathetic system conveys pain sensation from most of the viscera. The cell bodies of the sensory fibres are located in the dorsal root ganglia of T1 –L2 spinal nerves. The peripheral processes of the cell bodies of the sensory fibres of the sympathetic system pass through the trunk of spinal nerve, white rami communicantes, sympathetic ganglia(without synapsing) in the trunk, splanchnic branches and finally to the target organs (Fig. 10.9). The central processes of the cell bodies in the dorsal root ganglia reach the spinal cord through the dorsal nerve roots and make synaptic connections with the cell bodies of the preganglionic neurons in the intermedio-lateral column. Therefore, the localisation of pain fibres from individual viscera corresponds to the spinal segments from which the preganglionic fibres of the particular viscera arise.

The principal neurotransmitter released by the preganglionic sympathetic neurones is acetylcholine and that of the postganglionic neurones is noradrenaline. The sympathetic system has a much wider distribution than the parasympathetic system. It innervates all sweat glands, arrector pili muscles, muscular walls of many blood vessels, heart, lungs, respiratory tree, abdomino-pelvic viscera, oesophagus, muscles of the iris of eye and non-striated muscles of urogenital tract and several other viscera.

The postganglionic sympathetic fibres that return to the spinal nerves are:

- Vasoconstrictor to blood vessels,
- Secretomotor to sweat glands and motor to arrector pili muscles.

The postganglionic sympathetic fibres which—

- Accompany the motor nerves to voluntary muscles are dilatatory,
- Reach the viscera are concerned with generalised vasoconstriction, bronchial and bronchiolar dilatation, pupillary dilatation, inhibition of alimentary secretion etc.,

SYMPATHETIC TRUNK

The component of trunks are a pair of long nerve cords extending from the base of skull to the coccyx, and bear a number of ganglia along its length. In the neck, each trunk lies posterior to the corresponding carotid sheath and anterior to the transverse processes of the cervical vertebrae. In the thorax, the trunk descends in front of the heads of the ribs, and enters the abdomen behind the medial arcuate ligament where it is anterolateral to the lumbar vertebrae. The intercostal nerves and posterior intercostal vessels pass behind the trunk in the thoracic region. Lower down, the trunk descends anterior to the sacrum and passing medially, it joins its fellow of the opposite side in front of the coccyx to form an unpaired ganglion called the ***ganglion impar*** (Latin.impar=unpaired; also called the ***coccygeal ganglion*** or ***Walther's ganglion***; named after the 17th century German anatomist August Walther).

Initially (during evolution and development) the sympathetic trunk is supposed to have borne one ganglion (on each side) for each of the 31 pairs of spinal nerves, but the number is reduced by fusion of some of the ganglia.

In the cervical region, there are usually three ganglia: superior, middle and inferior. The upper four fuse to form the superior cervical ganglion, fifth and sixth unite to form the middle cervical ganglion and the seventh and eighth form the inferior cervical ganglion. The first thoracic ganglion sometimes fuses with the inferior cervical ganglion, forming the ***cervicothoracic ganglion,*** otherwise called the ***stellate ganglion***.

There are usually eleven ganglia in the thorax, four in the lumbar region, and four or five in the sacral region.

All the ganglia in the sympathetic trunk are connected to the corresponding spinal nerve by grey rami communicans. However, the ***thoracic*** and upper two ***lumbar sympathetic ganglia*** are connected with the corresponding spinal nerve by both ***grey and white rami communicantes***. White rami communicans convey ***preganglionic fibres*** from the thoracolumbar outflow and ***sensory sympathetic fibres*** from the viscera to the cells of the dorsal nerve root ganglia, whereas, the grey rami communicans convey post ganglionic fibres to the skin, hair and blood vessels through all the ganglia in the sympathetic trunk. Therefore, the preganglionic sympathetic fibres pass only through the thoracic and upper two lumbar spinal nerves.

Thus the nerve fibres of the sympathetic trunks are composed of ascending and descending branches of preganglionic and postganglionic neurons, and the afferent (sensory) sympathetic fibres.

Branches of Sympathetic Trunk (Fig. 10.8)

Cardiac Branches from the Cervical Part of Sympathetic Trunk

Each of the three pairs of cervical ganglion gives off a cardiac branch totalling six cardiac branches (three right and three left). The left superior cervical cardiac branch descends into the thorax along the common carotid artery.

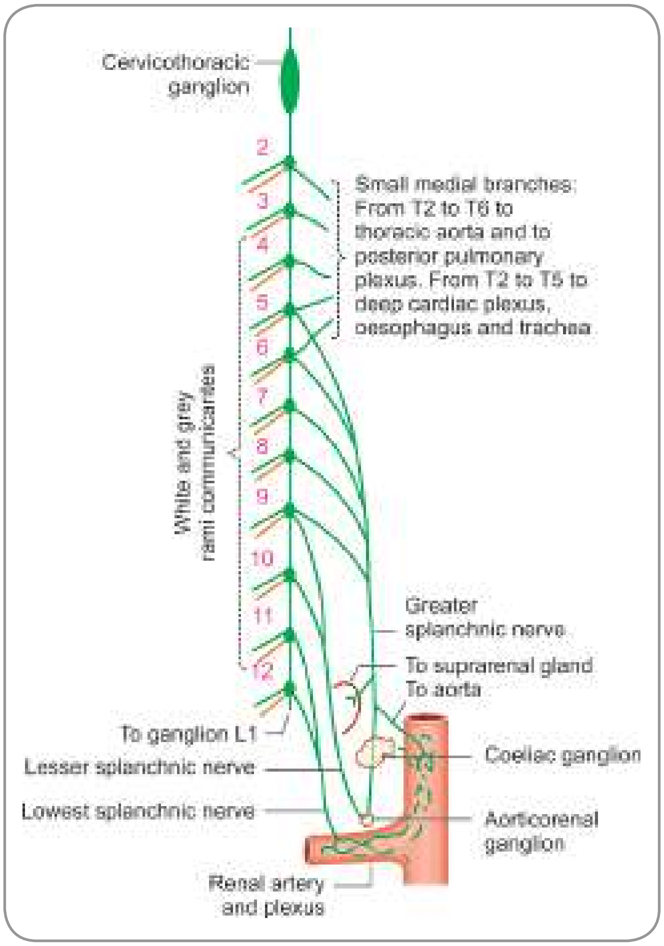


Fig. 10.8: Branches of the thoracic part of the sympathetic trunk

It runs across the lateral side of the arch of aorta and ends in the superficial cardiac plexus.

All other cervical sympathetic cardiac branches (left middle and inferior; right superior, middle and inferior) end in the deep cardiac plexus.

(Other branches of the cervical sympathetic trunk will be detailed in the chapters on the appropriate regions).

Branches from the Thoracic Part of Sympathetic Trunk

The eleven thoracic ganglia give off medial and lateral branches.

The lateral branch arising from each ganglion connect it to the corresponding spinal nerve by white and grey rami communicans as already described.

The medial branches arising from the ganglia supply the viscera. Those arising from the ***upper thoracic ganglia*** are small. They supply the thoracic aorta (T2 to T6), join the posterior pulmonary plexus (T2 to T5/6), or join the deep cardiac plexus (T2 to T5). Some of them supply the trachea and the oesophagus.

The ***lower thoracic ganglia*** give origin to prominent medial branches called the ***greater, lesser and lowest splanchnic nerves***. Their origin is highly variable. The splanchnic nerves contain both preganglionic efferent nerve fibres and visceral afferent fibres.

- The ***greater splanchnic nerve*** is usually formed by branches from ganglia T5 to T9.
- The ***lesser splanchnic nerve*** is formed by branches from ganglia T9 to T10 or T10-T11.
- The ***lowest splanchnic nerve*** is formed from ganglion T12. All these nerves pass through the diaphragm and enter the abdomen.
  - The greater splanchnic nerve ends mainly in the ***coeliac ganglion.***
  - The lesser splanchnic nerve ends in the ***aorticorenal ganglion.***
  - The lowest splanchnic nerve (also called the least splanchnic or the renal nerve) ends in the ***renal plexus***.

Branches from the Lumbar and Sacral Part of Sympathetic Trunk

Four lumbar splanchnic nerves emerge as medial branches from the corresponding ganglia.

- The first lumbar splanchnic nerve joins the coeliac, renal and inferior mesenteric plexuses.
- The second lumbar splanchnic nerve joins the inferior part of inferior mesenteric plexus.
- The third lumbar splanchnic nerve joins the superior hypogastric plexus and
- The fourth lumbar splanchnic nerve joins the lower part of superior hypogastric plexus.

Two twigs from the upper two sacral ganglia (sacral splanchnic nerves) join the inferior hypogastric plexus to supply the pelvic viscera.

Distribution of the Thoracolumbar Outflow of the Sympathetic Trunk

- ***Head and neck:*** The preganglionic fibres from T1 and T2 segments ascend up through the trunk and relay in the superior, middle and inferior cervical ganglia to supply the head and neck.
- ***Upper limb:*** The preganglionic fibres from T2–T7 segments ascend up through the trunk and relay in the inferior cervical and first thoracic ganglia. The post ganglionic fibres join the brachial plexus to supply the upper limb (mainly vasoconstrictor to the blood vessels).
- ***Lower limb:*** The preganglionic fibres from T10–L2 segments descend down through the trunk and relay in the lower lumbar and upper sacral ganglia. The post ganglionic fibres join the lumbosacral plexus mainly the femoral nerve and to some extent, the obturator nerve and supply the lower limb (mainly vasoconstrictor to the blood vessels).
- ***Heart:*** Preganglionic nerves are from T2–T5; postganglionic nerves form cardiac plexus from three cervical

and upper four or five thoracic ganglia. These nerves act as cardio-accelerators and vasodilators of heart.

- Pain sensations from the heart reach the dorsal nerve root ganglia of the same segments (T2–T5) spinal nerves, via the cardiac branches of middle cervical, inferior cervical and upper thoracic ganglia.
- ***Lungs:*** Preganglionic nerves are from T2–T5/6; postganglionic nerves form pulmonary plexus and are bronchodilator and vasoconstrictor in action.
- ***Pre-ganglionic centres of other abdomino-pelvic organs:***
  - Oesophagus and stomach: T6–T9
  - Small intestine: T9–T10
  - Large intestine: T11–L2
  - Supra-renal gland: T8–L1
  - Kidney: T10–L1
  - Urinary bladder: T11–L2
  - Testes/ovary: T10–T11
  - Uterus: T12–L1

Clinical Correlation

- Thoracic sympathectomy is a method of choice to treat intractable severe hyperhidrosis (excessive sweating) of the palms. It is also done to treat end stage Raynaud's disease with peripheral ulcers though the effect may be temporary. Raynaud's disease is caused by vasospasm of the upper limb. Surgical section of the sympathetic trunk below T3 ganglion is done.
- An inadvertent injury to the stellate ganglion and interruption of sympathetic fibres from T1 can lead to Horner's syndrome. It is manifested by constricted pupil, drooping of upper eyelid, enophthalmos and absence of sweating of the ipsilateral half of face and forehead.

Innervation of Thoracic Viscera

The most important thoracic viscera are the heart and the lungs. Both the heart and lungs are subserved by autonomic nerves.

Nerve Supply of Heart

The heart is supplied by nerves passing through the superficial and deep cardiac plexuses.

- ***Parasympathetic preganglionic neurons*** for the heart are located in the medulla oblongata of the brain (dorsal nucleus of vagus). They reach the heart through the cardiac branches of the vagus.
- ***Parasympathetic postganglionic neurons*** are located within the superficial and deep cardiac plexuses and also in the walls of the atria.
- ***Preganglionic sympathetic neurons*** are located in segments T1 to T5 of the cord. On reaching the sympathetic trunk, their axons synapse with ***postganglionic neurons*** in the upper thoracic ganglia. Some of them run upwards in the sympathetic trunk to end in the cervical ganglia. Postganglionic fibres leave these ganglia through their cardiac branches and join the vagal fibres in forming the cardiac plexuses.

Contraction of cardiac muscle is not dependent on nerve supply. It can occur spontaneously. The nerves supplying the heart, however, influence the heart rate. Sympathetic stimulation increases heart rate and parasympathetic stimulation slows it. Sympathetic nerves supplying the coronary arteries cause vasodilatation thereby increasing blood flow through them.

Afferent fibres from the heart travel through both sympathetic and parasympathetic pathways. Impulses of pain arising in the heart travel along sympathetic pathways. They are carried mainly by the cardiac branches of the middle and inferior cervical ganglia. Some fibres also pass through cardiac branches of thoracic ganglia. These fibres pass through the sympathetic trunks and enter the spinal cord through spinal nerves T1 to T5. The cell bodies of the neurons concerned are located in the dorsal nerve root ganglia on these nerves. These pathways convey impulses of pain produced as a result of anoxia of heart muscle (angina) (Fig. 10.9).

Afferent fibres running along the vagus are concerned with reflexes controlling the activity of the heart.

Nerve Supply of Lungs and Bronchi

Parasympathetic preganglionic neurons which supply the bronchi are located in the dorsal nucleus of vagus. The fibres travel through the vagus and its branches, to reach the anterior and posterior pulmonary plexuses. Postganglionic neurons are located near the roots of lungs. Their axons run along the bronchi and supply them.

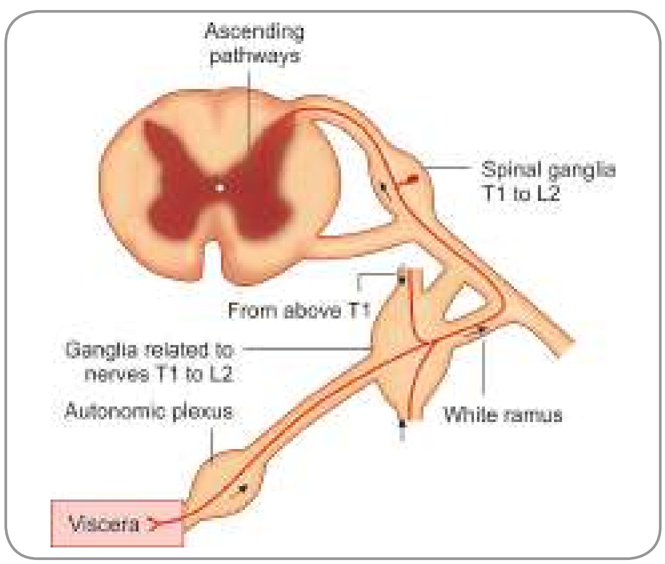


Fig. 10.9: Afferent autonomic pathway involving the sympathetic nerves

- ***Sympathetic preganglionic neurons*** concerned are located in spinal segments T2 to T5. Their axons terminate in the corresponding sympathetic ganglia. Postganglionic fibres arising in these ganglia reach the bronchi through branches from the sympathetic trunks to the pulmonary plexuses.
- Parasympathetic stimulation causes bronchoconstriction, while sympathetic stimulation causes bronchodilatation. Parasympathetic stimulation also produces vasodilatation and has a secretomotor effect on the mucous glands in the bronchi. Sympathetic stimulation produces vasoconstriction.

Afferent fibres arise in alveoli and bronchial mucosa. They are important in respiratory reflexes.Con remporrum rem quibus experia culliamus arum inus et re verovitae. Ita dolorerchiti blaborro dollauta non

Multiple Choice Questions

1. Autonomic nerves which supply glands are called:
   a. Glandular
   b. Secretoglandular
   c. Secretomotor
   d. Motoglandular

2. The superficial cardiac plexus is located:
   a. Near the ligamentum arteriosum
   b. Near the trachea
   c. Near the apex of heart
   d. Near the superior vena cava

3. The sympathetic neurons located along the aorta and its branches form:
   a. Vascular ganglia
   b. Retroperitoneal ganglia
   c. Collateral ganglia
   d. Linear ganglia

4. Stellate ganglion is the:
   a. Cervicothoracic ganglion of the parasympathetic trunk
   b. Cervicothoracic ganglion of the sympathetic trunk
   c. Inferior cervical ganglion of the sympathetic trunk
   d. Inferior cervical ganglion of the parasympathetic trunk

5. Parasympathetic stimulation of the lungs causes:
   a. Bronchoconstriction and mucous secretion
   b. Bronchodilatation and mucous secretion
   c. Vasoconstriction and Bronchoconstriction
   d. Vasoconstriction and mucous secretion

ANSWERS

1. c **2.** a **3.** c **4.** b **5.** a

Clinical Problem-solving

Case Study 1: A 54-year-old man complained of pain in the lateral area of shoulder.
- With your anatomy knowledge in the background, which internal structure/organ would you suspect to be the source of pain?
- Can you give the neuroanatomical basis for such a pain?
- What is the phenomenon called?

Case Study 2: A 47-year-old woman suffers from Raynaud's disease.
- What happens in Raynaud's disease?
- Which part of the nervous system is involved?
- How can the disease be treated?

(For solutions see Appendix).

Chapter 11

Cross-Sectional, Radiological and Surface Anatomy of Thorax

Frequently Asked Questions

- Write notes on: (a) X-ray chest, (b) Echocardiography, (c) Carina.
- Draw a neat diagram of the transverse section of the thoracic cavity at the level of T5 vertebra. Label its various parts.
- Write briefly on: (a) Surface marking of lungs, (b) Surface marking of right border of heart, (c) Counting of ribs in the living.

CROSS-SECTIONAL ANATOMY OF THORAX

The thoracic cavity is filled with important viscera. The knowledge of their relationships is important in diagnosis of diseases, analyses of investigative procedures and in treatment decisions. Though cross-sectional information at every vertebral level is important, two important levels are discussed here in view of the structural and topographic changes which take place at these levels.

TRANSVERSE SECTION AT THE LEVEL OF THE UPPER PART OF T4 VERTEBRA (FIG. 11.1)

This section cuts through the superior mediastinum. Major part of the section is occupied by the right and the left lungs with the structures of the superior mediastinum in between. The most important structure seen at this level is the arch of aorta. Since the arch is vertically disposed and the section is transverse, the section cuts through the arch, which is seen as a half-cut oblique tube. The origins of brachiocephalic, left common carotid and left subclavian arteries are seen within the arch. The oesophagus is seen anterior to the vertebral body and the trachea is present anterior to the oesophagus. The superior vena cava is present on the right side of the anterior end of the arch. Other noticeable mediastinal structures in this section are the thymus and thoracic duct, the latter being posterior and to the left of the oesophagus.

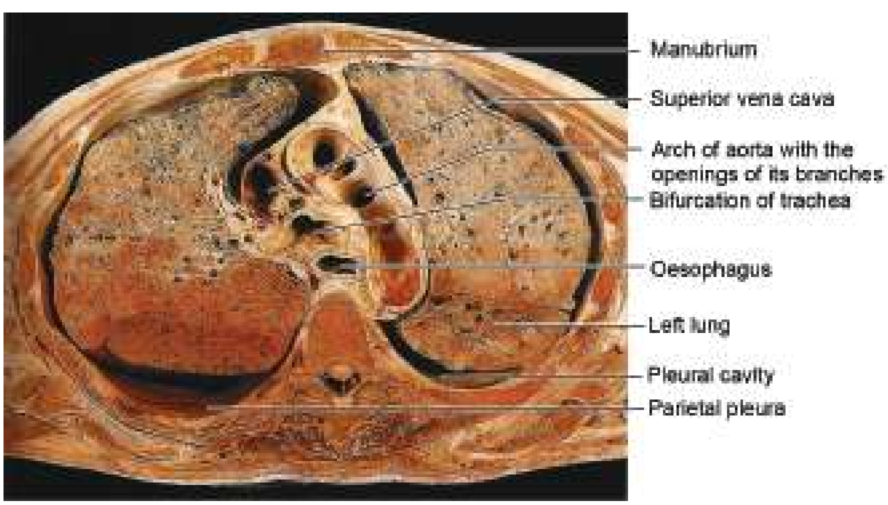


Fig. 11.1: Transverse section of thorax at the level of the upper part of T4 vertebra-inferior view

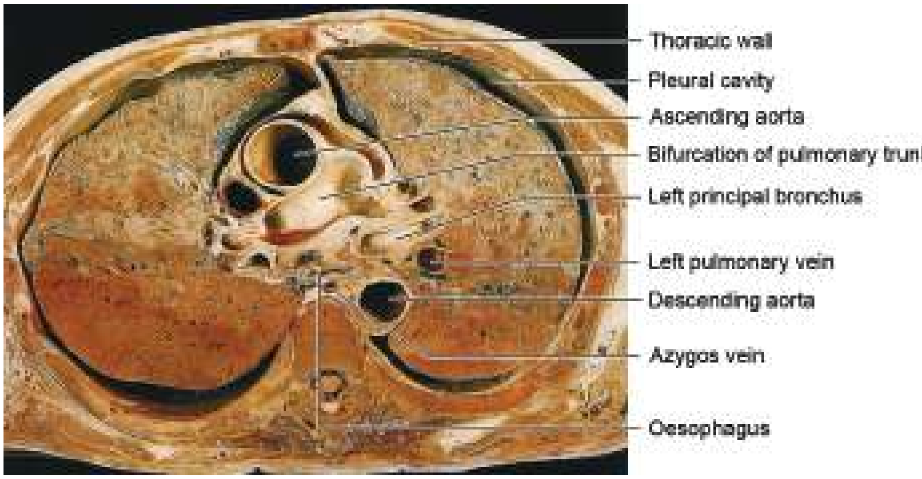


Fig. 11.2: Transverse section of thorax at the level of upper part of T5 vertebra-inferior view

TRANSVERSE SECTION AT THE LEVEL OF UPPER PART OF T5 VERTEBRA (FIGS 11.2 AND 11.3)

This section cuts through the junction of the superior and inferior mediastina. When the section passes through the intervertebral disc between T4 and T5, it is sometimes referred to as the ***angle of Louis section***. Anteriorly, it cuts through the manubriosternal junction and the second costal cartilage. As the arch of aorta had commenced and terminated, the ascending aorta is seen anterior to the pulmonary trunk and the descending aorta posterior to the pulmonary trunk. The bifurcation of the pulmonary

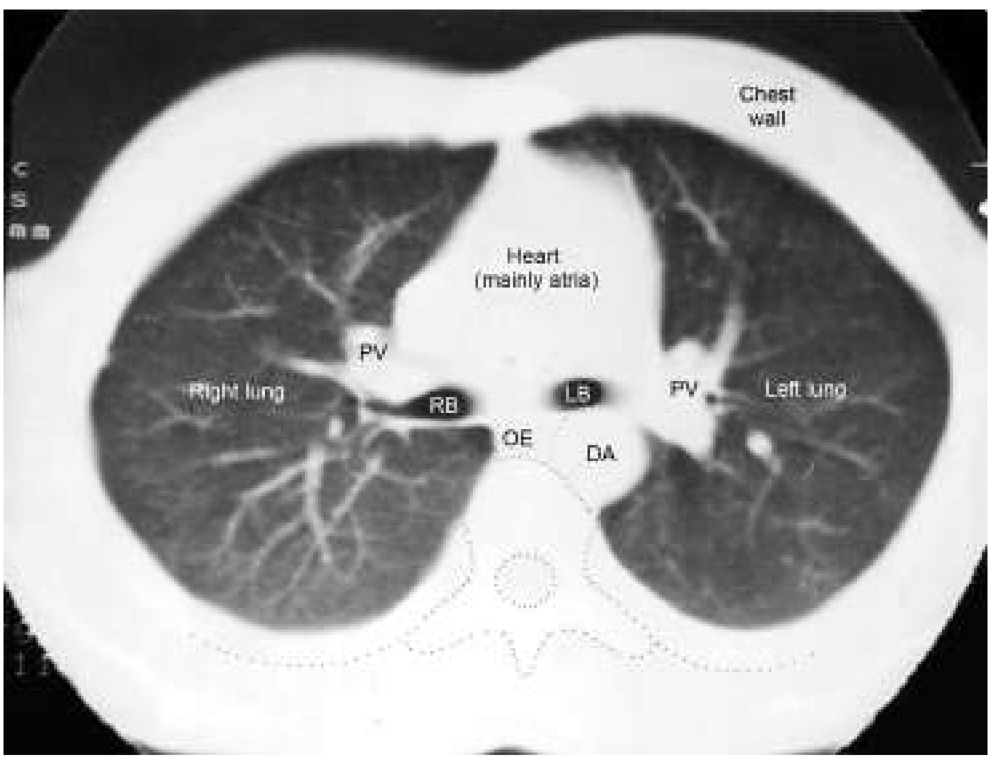


Fig. 11.3: Cross-section (axial section) of thorax obtained by CT scan. The section is viewed from the foot end of the patient. The section passes through the upper part of the heart (mainly atria), just below the level of the bifurcation of the trachea. The areas filled with air (lungs, lumen of bronchi) appear dark, while other structures appear light.

Key: DA. Descending thoracic aorta **OE.** Oesophagus **LB.** Left principal bronchus **RB.** Right principal bronchus **PV.** Pulmonary vessels. Ramifications of pulmonary vessels are seen as radiating shadows within the lungs.

trunk and the emerging right and left pulmonary arteries are seen between the two parts of the aorta. The terminal parts of the superior vena cava and the azygos vein are also made out. As the trachea divides just above this level, the right and the left principal bronchi are seen behind the bifurcation of the pulmonary trunk and in front of the oesophagus.The thoracic duct at this level is in the left side, posterior to the descending aorta. Other clinically important structures are the mediastinal lymph nodes found between the bronchi. Apart from the medistinal structures, major part of the section is filled with the right and left lungs with their pleura and hilar structures.

- ***Skeletal elements:*** The posterior parts of the ribs form a series of shadows running laterally and downwards. The anterior parts of ribs are seen (in the lateral part) as less prominent shadows curving downwards and medially (The costal cartilages do not cast any shadows). The vertebrae can be made out in the upper part of the radiograph. Lower down, the vertebrae and the sternum cannot be made out as they are overlapped by the shadow of the heart, and of structures in the mediastinum. The clavicle and scapula are seen, on each side, in the upper lateral part of the radiograph.
- The ***heart*** casts a shadow as it is full of blood. The right and left borders of the heart can be made out. When traced upwards, the left border becomes continuous with a shadow convex to the left. This shadow is produced by the arch of aorta and is referred to as the aortic knuckle. Just below the aortic knuckle, the border of the heart shadow represents the pulmonary trunk. When this is enlarged it may be seen as a projection called the ***pulmonary conus***. The right border of the heart merges, above and below, with the corresponding vena cava.
- The ***areas occupied by the lungs*** are seen as dark areas (as they are full of air). However, just lateral to the cardiac shadow irregular shadows are produced by structures in the hilum of each lung.
- The ***shadow cast by the diaphragm*** (and structures below it). The right dome of diaphragm is higher than the left.

RADIOLOGICAL ANATOMY OF THORAX

In November 1895, Wilhelm Conrad Roentgen discovered some waves belonging to the spectrum of electromagnetic radiation and called them X-rays despite not knowing all their properties at that point of time. The method of obtaining X-ray shadow pictures has subsequently been utilized in medical diagnostics.

By the early 1900s, radiography was being used as a diagnostic tool especially for the chest region in several countries including India. Even after a century, X-ray study of the chest remains a standard and oft-used method. A plain X-ray chest reveals several important information. The thoracic cavity is well disposed for an X-ray study because of the grid provided by intermingled areas of radiopacity and radiolucency. The bony components of the thoracic cage are well seen.

PLAIN X RAY CHEST (FIGS 11.4 AND 11.5)

A plain skiagram (X-ray picture) of the chest (Postero anterior or PA view) is the most common investigation for detecting structural abnormalities within the chest. It provides useful information about the bones of the thorax, the lung fields, the heart, the diaphragm and the mediastinum. In some cases it can establish diagnosis (e.g., in pleural effusion), and in many others it may give clues that aid further investigation.

The lung fields should be studied. The markings at the hila are prominently seen; exaggerated hilar markings should be looked for. The heart and other structures produce a shadow in which several individual prominences can be recognised. Along the left border of the shadow, prominences (from above downwards) seen are the aortic arch, the pulmonary artery, the left auricle and the left ventricle. Along the right border of the shadow, these are (from above downwards) the superior vena cava and the right atrium. The inferior border of the shadow is formed mainly by the right ventricle. Enlargement of any of these structures can produce alterations in the appropriate part of the heart shadow. The heart shadow in a radiograph can be studied with reference to the costal cartilages and ribs and the dimensions of the sternocostal surface made out. If the shadow exceeds the normal limits, it can be deduced that the heart is enlarged (cardiomegaly).

Right and left oblique views are also sometimes used.

Fluoroscopy or Screening

In this procedure, instead of recording the image on film, X-ray images are seen on a fluorescent screen. Although, less detail is seen than in a X-ray film, the technique allows a dynamic study. For example, movements of the domes of the diaphragm associated with inspiration can be visualised.

Bronchoscopy (Fig. 11.7) and Bronchography (Fig. 11.8)

- The interior of the trachea and bronchi can be visualised through an instrument called the ***bronchoscope***. Earlier bronchoscopes were rigid and could be passed only into larger bronchi. More recent bronchoscopes, based on fibre optics, are flexible and can be passed into smaller bronchi.
- Apart from examining the interior of the bronchial tree, bronchoscopy can also be used to obtain bronchial

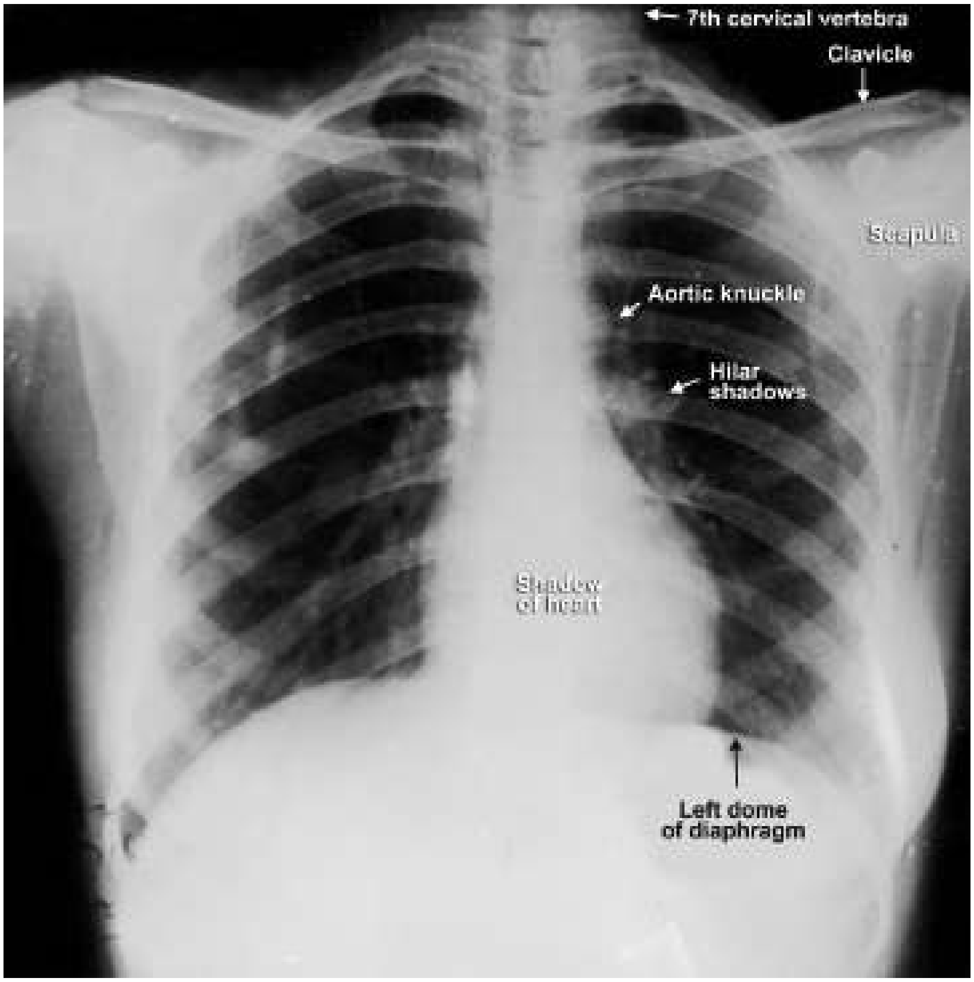


Fig. 11.4: Plain radiograph of the chest. Posteroanterior view, in a female adult

secretions and tissue for examination or to remove foreign bodies that may enter the bronchi.

- At the bifurcation of the trachea, the openings of the principal bronchi are seen, which are separated by a ridge called the ***carina*** (Fig. 11.7). The appearance of the carina alters in carcinoma and can thus help in diagnosis.
- ***Bronchography*** is a procedure in which X-ray pictures of the bronchi can be obtained after instilling a radio-opaque substance into them.

Coronary Angiography

Visualisation of the coronary vessels and their branches is possible by injecting contrast dye into them. This procedure is called ***coronary angiography*** and the picture thus obtained is a coronary angiogram. Sites of narrowing of the vessels can be determined.

Echocardiography

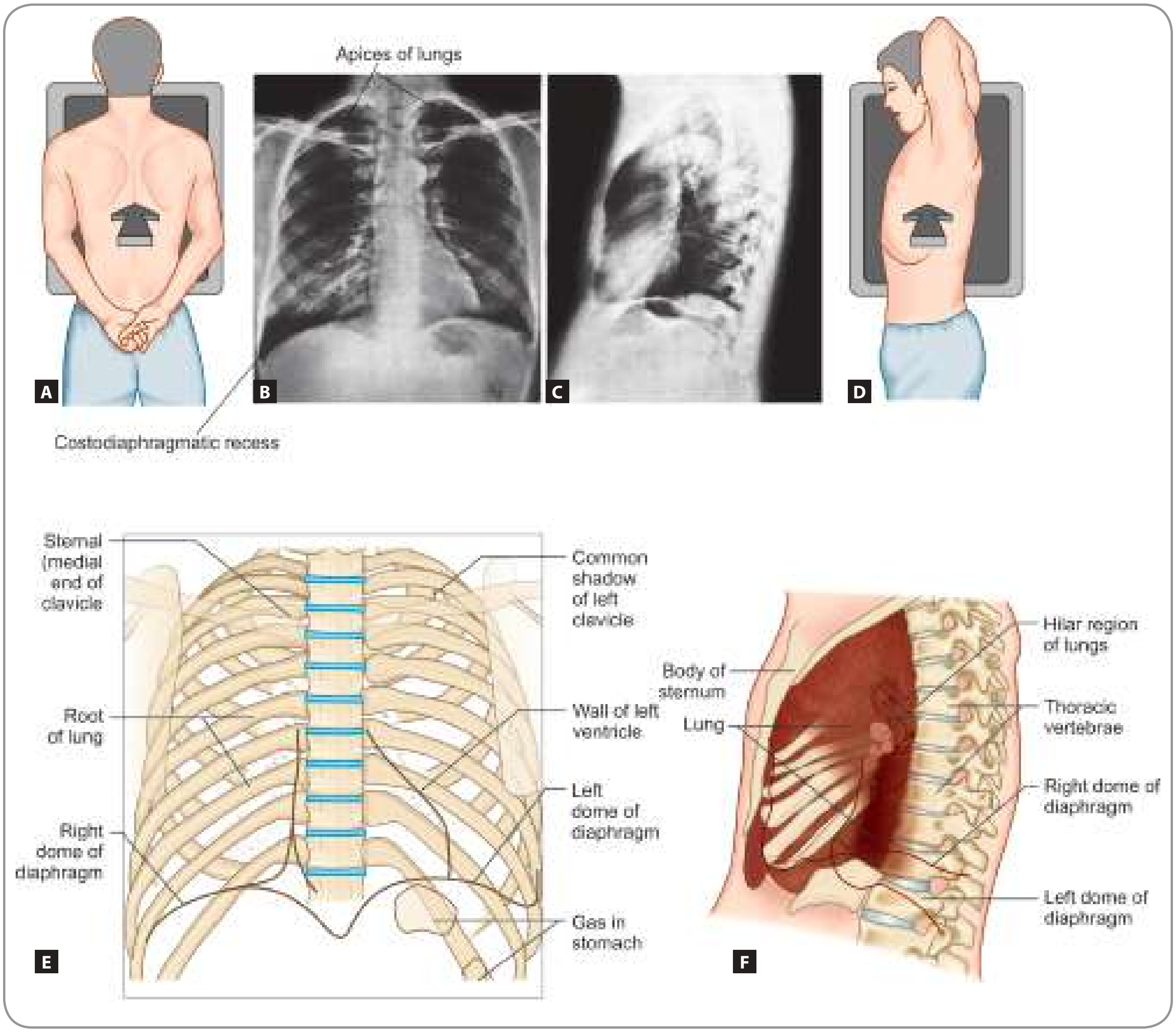
Otherwise called ultrasonic cardiography, this technique records the position and movements of the heart by echoes obtained from ultrasonic waves sent in. Even very small lesions and collection of very little pericardial fluid can be detected by this method. Doppler echocardiography records blood flow through the various chambers and vessels. Apart from the volume of flow, velocities can also be measured.

PALPATION OF IMPORTANT FEATURES

Palpating and Counting of Ribs

The ribs and intercostal spaces are used as reference points for several internal structures. It is, therefore, essential to learn to identify a rib and an intercostal space by their numbers. The easy procedure for this would be to count the ribs and fix their numbers.

The clavicle (on any side or the required side) is palpated. The expanded medial end is felt for. One examining finger is placed in the interval between the medial ends of the right and left clavicula and the upper border of the manubrium sterni is palpated. This border is concave and lies at a distinctly lower level than the



Figs 11.5A to F: Thoracic radiography **A.** Orientation for posteroanterior (PA) projection (arrow = X-ray beam) **B.** PA radiograph of thorax (viewed in AP position) **C.** Lateral radiograph of the thorax (chest) **D.** Orientation for a lateral radiograph (arrow = X-ray beam) **E.** Schematic drawing of PA radiograph **F.** Schematic drawing of lateral radiograph

medial ends of the clavicula. The examining finger is ran down on the manubrium sterni (in the midline) till a ridge-like prominence is reached. This prominence is the manubriosternal junction or ***sternal angle***. At this level, the examining finger is passed laterally; the finger runs on to the ***second costal cartilage***. The second costal cartilage meets the sternum at the junction of the manubrium and the body of the sternum. Passing further laterally along the second costal cartilage, the second rib can be felt.

Once the second rib is felt and identified, it can be used as a landmark for counting the rest of the ribs. Other ribs and costal cartilages by counting downwards from the second.

Each rib is laterally traced up to the midaxillary line. The lowest rib palpable on this line is the tenth rib. The ribs can be traced beyond the midaxillary line onto the back of the thorax.

Palpating and Counting of Vertebral Spines

The ligamentum nuchae is felt at the back of neck on the midline. When the examining finger is run down the midline, it reaches the spine of the 7th cervical vertebra. Thoracic vertebral spines can be identified by counting downwards from here.

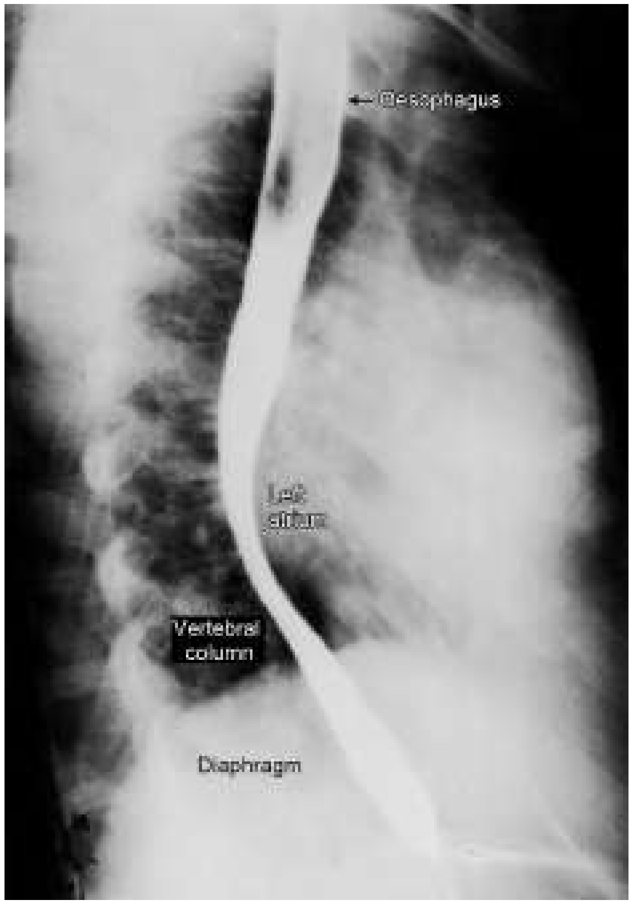
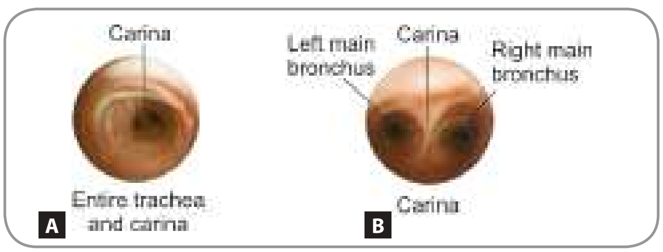


Fig. 11.6: Radiograph taken immediately after the patient is made to swallow a suspension of barium sulphate (which is opaque to X-rays). The oesophagus is clearly outlined. Any defects in the lumen produced by disease can be made out. An enlarged left atrium (abnormal) produces an indentation on the shadow of the oesophagus



Figs 11.7A and B: Bronchoscopies view **A.** Carina seen through trachea **B.** View at the level of carina

IMPORTANT LINES AND AREAS

- ***Midsternal line:*** The midline of the body on the anterior chest wall; it is the intersection of the midsagittal plane with the anterior chest wall; it is otherwise called the 'anterior median line'.
- ***Midclavicular line:*** This is the vertical line drawn from the midpoint of clavicle down the anterior chest wall.
- ***Anterior axillary line:*** This is the vertical line drawn along the anterior axillary fold and continued down the chest wall.
- ***Posterior axillary line:*** This is the vertical line drawn along the posterior axillary fold and continued down the chest wall.
- ***Midaxillary line:*** This is the line drawn from the deepest part of the axillary fossa down the chest wall, parallel to the anterior axillary line.
- ***Midvertebral line:*** This is the line drawn along the spines of vertebra and is the midline of the body on the posterior aspect; it is also called the posterior median line.
- ***Scapular line:*** This is the line drawn along the inferior angle of scapula; it is parallel to the midvertebral line.

SURFACE ANATOMY OF THORAX

STRUCTURES/VISCERA OF THE RESPIRATORY TRACT

Trachea

Point A is marked immediately below the arch of cricoid cartilage. Point B is marked 1 cm to the right of the midline on the sternal angle. The two points are joined a broad line (about 2 cm wide).

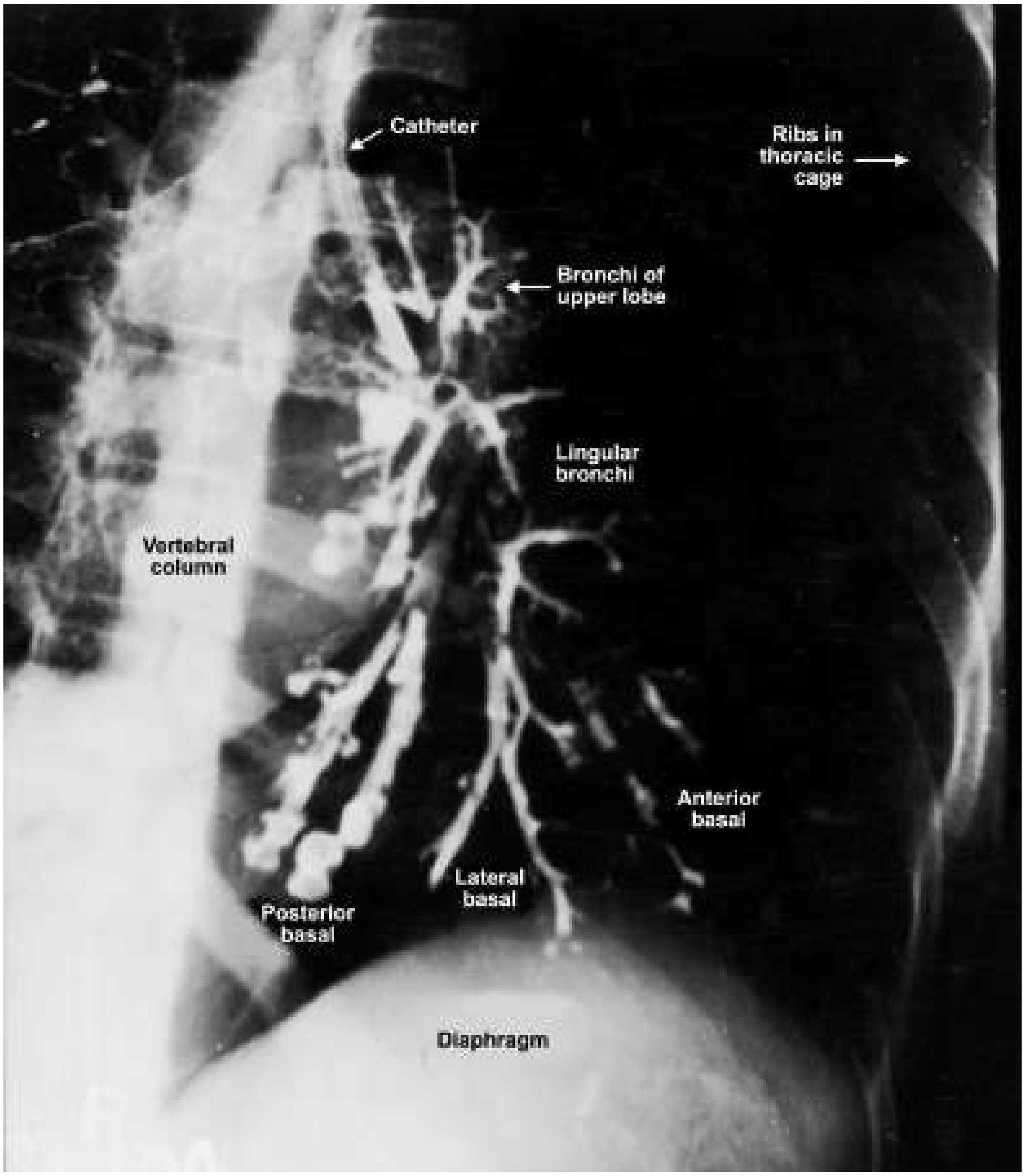


Fig. 11.8: Bronchogram showing bronchi of the left lung (oblique view). A catheter is passed into the trachea, and then into the left principal bronchus, and a contrast medium is injected to outline the bronchi.

Right Principal Bronchus

Point A is marked 1 cm to the right of the midline on the sternal angle. Point B is marked on the sternal end of the right third costal cartilage. The right principal bronchus is marked by drawing two lines 1 cm apart, running downwards and to the right, joining these two points.

Left Principal Bronchus

Point A is marked 1 cm to the right of the midline on the sternal angle. Point B is marked on the left third costal cartilage, 4 cm from the median plane. The two points are joined by a broad line that is 1 cm wide.

Pleura

Right Costomediastinal Reflection

Point A is marked on the right sternoclavicular joint. Point B is marked on the midline at the level of sternal angle. Point C is marked on the xiphisternal joint 1 mm to the right of the midline. Points A and B are joined by a line that slopes downwards and medially; points B and C are joined by a line that runs almost vertically down.

Left Costomediastinal reflection

Point A is marked on the left sternoclavicular joint. Point B is marked on the midline at the level of sternal angle. Point

C is marked on the midline at the level of the 4th costal cartilage. Point D is marked on the xiphisternal joint 2 mm to the left of the midline (that is, left edge of xiphisternal joint). Points A and B are joined by a line that slopes downwards and medially; points B and C are joined by a line that runs vertically down. Points C and D are joined by a line that is carried to the left border of the sternum and reaches point D at the left edge of the xiphisternal joint.

Costodiaphragmatic Reflection

This is the same on both sides, except for the anterior end.

Point A is marked (for the right side) on the xiphisternal joint 1 mm to the right of the midline. The same point A (for the left side) is marked on the left edge of the xiphisternal joint.

The rest of the course of the reflection is marked by the same reference points on both sides. Point B is marked on the midclavicular line at the point where the line crosses the 8th rib. Point C is marked on the midaxillary line at the point where the line crosses the 10th rib. Point D is marked on the tip of the twelfth costal cartilage (or 2 cm lateral to the T12 spine). All the points are joined by a line that is slightly curved with the convexity facing downward so that the maximum level of convexity is on the midaxillary line.

On the right side, this line will cross the right costo-xiphoid angle (on the anterior aspect) and the right costo-vertebral angle (on the posterior aspect). On the left side, the line of costo-diaphragmatic reflection will cross only the costo-vertebral angle.

Costovertebral Reflection

This is the same on both sides.

Point A is marked 2 cm (on the corresponding side) lateral to the T2 spine. Point B is marked 2 cm lateral to the T12 spine. The two points are joined by a vertical line.

Cervical Pleura

Point A is marked on the sternoclavicular joint. Point B is marked on the clavicle at the junction of its medial third with the lateral two-thirds. Point C is marked 3 cm above the clavicle but midway between points A and B. The three points are joined by a curved line convex upwards running from point A to C and then from C to B.

Lung

- In visualising the surface projection of the lung, it may be remembered that as the lungs are surrounded by pleura, the limits of the lung must always lie within the boundaries of the pleura, already defined. In some situations, the boundaries are the same as that for the pleura, but in other situations the lungs fall short of the pleura. This is most evident near the costodiaphragmatic reflection of the pleura, where the costal and diaphragmatic pleura are separated by a potential space called the ***costodiaphragmatic recess***. A similar space called the ***costomediastinal recess*** is present in relation to the anterior border of the left lung.
- It should also be remembered that the limits of the lung described below represent the position in quiet respiration. In deep inspiration, the lungs extend much deeper into the costodiaphragmatic and costomediastinal recesses.
- The ***outline of the apex*** of the lung corresponds to that of the cervical pleura.
- The ***anterior border of the right lung*** corresponds to the costomediastinal reflection of the pleura described above.
- The ***anterior border of the left lung*** up to the fourth costal cartilage follows the pleura, but below this level the border falls considerably short of the pleura because of the presence of the deep cardiac notch. From the midline (at the level of the fourth costal cartilage) the border passes sharply to the left and downwards so that at the level of the fifth costal cartilage it is about 3.5 cm lateral to the sternal margin (or to the line for the pleura). It then curves downwards and medially to reach the sixth costal cartilage a short distance lateral to the line for the pleura (i.e., about 4 cm from the midline).
- The ***inferior border of the lung*** follows a curved line lying above that for the costodiaphragmatic reflection of the pleura. On each side, the line representing the lower border begins anteriorly at the lower end of the anterior border. In the midaxillary line, it lies over the eighth rib. Its posterior end lies at the level of the tenth thoracic spine 2 cm lateral to the midline.
  - Note that there is a difference of two ribs in the levels of the lung and pleura over both these lines.
- The ***posterior border of the lung*** lies 2 cm from the midline. It extends below to the level of the tenth thoracic spine and above to the level of the second thoracic spine. When seen from behind, the apex of the lung lies at level of the first spine about 5 cm from the midline.
- ***Oblique Fissure of Lungs:***
  - Point A is marked 2 cm lateral to the third thoracic spine; point B is marked 3 cm lateral to and at the level of nipple; point C is marked on the sixth costal cartilage 7.5 cm from the midline. Points A and B are joined by a line that crosses the scapula and is almost parallel to the posterior border of deltoid muscle. Points B and C are joined and the line joining them carries the oblique fissure downwards and medially.
- ***Transverse Fissure of Right Lung:***
  - Point A is marked on the midline at the level of fourth costal cartilage. A transverse line is drawn from the above point along the right fourth costal cartilage upto the right mid axillary line, where it meets the oblique fissure.

Viscus of the Cardiac System

Heart

On the anterior chest wall: For this projection, the heart has a superior border, an inferior border, a right border and a left border. In addition, it has an apex.

- ***Superior border:*** Point A is marked on the upper border of the third right costal cartilage about 1 cm from the sternal margin. Point B is marked on the lower border of the second left costal cartilage about 1 cm from the sternal margin. These two points are joined by a straight line. It will be seen that this line slopes upwards from right to left.
- ***Inferior border:*** Point C is marked on the sixth right costal cartilage about 1 cm from the sternal margin. Point D is marked on the fifth left intercostal space immediately medial to the midclavicular line. These two points are joined by a line which is slightly convex downwards at its right and left ends and slightly concave downwards in the middle.
- ***Right border:*** This border extends from the third right costal cartilage to the sixth right costal cartilage. Thus point A (the right end of the superior border) and point C (the right end of the inferior border) are connected by a line which is convex, the maximum convexity being in the fourth intercostal space.
- ***Left border:*** This border extends from the second left costal cartilage to the apex beat of the heart. Thus point B (the left end of the superior border) and point D (the left end of the inferior border) are connected by a line which is convex to the left.
- ***Apex of the heart:*** This is marked on the fifth left intercostal space immediately medial to the midclavicular line.

Valves of the Heart

All the four important valves can also be projected on the surface, on a line connecting points B and C mentioned above.

- The ***pulmonary valve*** is about 2.5 cm broad and lies partly behind the left third costal cartilage, and is partly behind the sternum.
- The ***aortic valve*** is about 2.5 cm broad. It is placed obliquely behind the left half of the sternum at the level of the third intercostal space.
- The ***mitral valve*** is about 3 cm wide. It is placed obliquely deep to the left half of the sternum at the level of the fourth costal cartilage.
- The ***tricuspid valve*** is about 4 cm broad. It is placed almost vertically behind the sternum. Its upper end lies in the midline at the level of the fourth costal cartilage. Its lower part inclines slightly to the right and reaches the level of the fifth costal cartilage.

Viscus of the Digestive System

Oesophagus

Point A is marked on the lower border of cricoid cartilage. Point B is marked on the upper border of manubrium sterni. Point C is marked on the midline a little below the sternal angle. Point D is marked on the left seventh costal cartilage 2.5 cm from the midline.

- ***Oesophagus in the neck and superior mediastinum:*** Points A and B and points B and C are joined by a broad line that is 2.5 cm wide. The line should be drawn in such a way that at the level of the cricoid cartilage and at the level of the sternal angle, the oesophagus is seen to be in the midline. At the level of the superior thoracic aperture (i.e., the upper border of manubrium sterni) the line should deviate slightly to the left.
- ***Oesophagus in the posterior mediastinum:*** Points C and D are joined by a broad line with a distinct inclination to the left.

Vessels

Internal Thoracic Artery

Point A is marked in the neck, 1 cm above the sternal end of the clavicle, 3.5 cm from the midline. Point B is marked in the sixth intercostal space 1.2 cm from the lateral border of the sternum. The line joining these two points runs downwards behind the upper six costal cartilages and lies about 1.2 cm lateral to the sternum. It indicates the internal thoracic artery on the surface.

Pulmonary Trunk

Point A is marked as a transverse line about 2.5 cm broad, partly over the left third costal cartilage and partly over the sternum. Point B is marked at the level of the left second costal cartilage, straight above point A. The two points are joined by a broad line that is 2.5 cm broad. The line indicates the pulmonary trunk on the surface.

Ascending Aorta

Point A is marked as an oblique line, about 2.5 cm broad, behind the left half of the body of sternum at the level of the third intercostal space. From the ends of this line, two parallel lines passing upwards and to the right are drawn to reach the right half of sternal angle.

Arch of Aorta

Point A is marked on the right extremity of the sternal angle. Point B is marked on the centre of manubrium. Point C is marked on the sternal end of the left second costal cartilage. The three points are joined by a line that curves up an reaches its maximum convexity at the manubrium sterni. This line will indicate the outer borer of the arch. Another line, about 2 cm below and parallel can be drawn to complete the picture.

Descending Thoracic Aorta

Point A is marked on the sternal end of the left second costal cartilage. Point B is marked on the midline 2 cm above the transpyloric plane. The two points are connected by a broad line about 2.5 cm wide. This line indicates the descending thoracic aorta on the surface.

Brachiocephalic Trunk

The outer convexity of the arch of aorta may first be marked. Point A is marked on the centre of manubrium sterni. Point B is marked on the right sternoclavicular joint. A line joining the two points indicates the brachiocephalic trunk on the surface. The line should be 8 mm broad.

Left Common Carotid Artery in Thorax

Point A is marked immediately to the left of the centre of manubrium (i.e., just to the left of the origin of the brachiocephalic trunk). Point B is marked on the left sternoclavicular joint. The two points are joined by a line that is 8 mm broad.

Left Subclavian Artery in Thorax

Point A is marked at the centre of the left border of manubrium sterni. Point B is marked on the left sternoclavicular joint (a little to the left of the left common carotid artery marking). A broad line connecting the two points indicates the left subclavian artery on the surface.

Superior Vena Cava

Point A is marked on the sternal end of the lower border of the right first costal cartilage. Point B is marked on the upper border of the third right costal cartilage. The two points are connected by a 2 cm broad line.

Right Brachiocephalic Vein

Point A is marked on the medial end of right clavicle. Point B is marked on the lower border of the first right costal cartilage. A line joining points A and B marks the right brachiocephalic vein on the surface.

Left Brachiocephalic Vein

Point A is marked on the medial end of left clavicle. Point B is marked on the lower border of the first right costal cartilage. A line joining points A and B marks the left brachiocephalic vein on the surface (running obliquely upwards and to the left).

LYMPHATIC VESSELS

Thoracic Duct

Point A is marked 2 cm above the transpyloric plane but slightly to the right of midline. Point B is marked on the sternal angle on the midline. Point C is marked 2 cm to the left of midline and 2.5 cm above the left clavicle. Point D is marked 1.2 cm lateral to point C. All the four points are joined serially in such a way that the line joining ascends up and then turns downwards to go behind the clavicle.

Sternal Angle and Reference to Internal Strutures

The plane of the sternal angle (also called the transverse thoracic plane) is used as a reference plane for localising internal structures. The plane, as such, is marked with reference to bony landmarks and hence, is almost constant. However, internal structures do not remain as constant as they are thought to be. Variations are seen depending on the position of the individual and the action of gravity. gravity exerts a pull on the viscera and the latter tend to sag or descend down. Most of the anatomical descriptions are done with reference to the supine position. Variations seen in upright and supine postures are:

- ***Position of arch of aorta:*** Superior to sternal angle in supine position and transected by the sternal angle plane in sitting/standing position;
- ***Bifurcation of trachea:*** Transected by the sternal angle plane in supine position and inferior to the sternal angle in sitting/standing position;
- ***Central tendon of diaphragm and inferior level of heart:*** At the level of Xiphisternal joint/T9 level in supine position and at the level of middle of xiphoid process/T9-T10 disc in sitting/standing position.

These factors should be remembered in clinical and radiological examination. If a person is lying on the sides, the mediastinum sags to the lower side due to gravity.

SUPERNUMERARY BONES ANATOMY

Cervical rib: The seventh cervical vertebra, may occasionally have a rib or a fibrous cord. The already congested area at the level of the superior thoracic aperture is further narrowed resulting in the cervical rib syndrome.

Multiple Choice Questions

1. Scapular line is drawn:
a. Along the inferior angle of scapula
b. Along the acromion of scapula
c. Along the lateral angle of scapula
d. Along the suprascapular notch of scapula

2. The heart casts a shadow in a X-ray picture because:
a. Myocardium has radiopaque salts
b. It is full of blood
c Pericardium is radiopaque
d. Its contraction produces the shadow

3. Ultrasonic cardiography is otherwise called:
a. Coronary angiography
b. Echocardiography
c. Angioplasty
d. Angiographic stenting

4. Fluoroscopy permits
a. More details to be seen
b. Study of movements
c. Visualisation of structures within structures
d. Calculation of blood flow

ANSWERS

1. a **2.** b **3.** b **4.** b

Clinical Problem-solving

Case Study 1: A 54-year-old man is being investigated upon.
- If you want to get an idea of his heart function and the blood flow through its different chambers, what procedure would you ask for?
- What is the higher variant of this procedure?

Case Study 2: If you are examining the chest X-ray of a 27-year-old patient, what are the features you would concentrate upon?

(For solutions see Appendix).

Section 5

Abdomen and Pelvis

Chapter 12

Overview of Abdomen and Pelvis

Frequently Asked Questions

- Write notes on the regions of abdomen.
- Explain the terms 'intraperitoneal', 'extraperitoneal' and 'retroperitoneal'. Give the anatomic and embryologic bases for these terms.
- Write short notes on: (a) Transpyloric plane, (b) Transtubercular plane, (c) Quadrants of abdomen.

Abdomen is the region between the thorax and the pelvis. It can be likened to a large and dynamic container that houses the viscera of the digestive, urinary and genital systems.

The anterolateral walls of the abdomen provide necessary support and stability to abdomen. These walls are musculoaponeurotic and are suspended between two bony rings. The superior bony ring is the inferior margin of the bony thoracic cage; the inferior ring is the pelvic girdle. Because of this arrangement, the abdomen is actually interposed between the more rigid thorax superiorly and the pelvis inferiorly. The anterolateral walls give the abdomen the flexibility needed for activities like respiration, locomotion and posture maintenance.

The anterolateral walls are helped by the muscular roof (diaphragm) and the muscular floor (muscles of pelvis). Together, all these muscles can contract to raise the intra-abdominal pressure, which is necessary to expel various contents of the cavity. Such expulsion can be voluntary, as in cases of expulsion of urine, flatus and faeces in the adults or reflexive, as in cases of expulsion of vomitus. The same phenomenon is brought into play during expulsion of foetus in females.

The same anterolateral walls are capable of considerable distension. This capacity is responsible for the expansions that the abdominal cavity may undergo during ingestion, pregnancy, deposition of adipose tissue and during certain diseases and conditions.

The cavity within the abdomen is the ***abdominal cavity***. It is a part of the coelomic cavity of the trunk. However, it is separated from the thoracic cavity by an almost complete muscular partition formed by the diaphragm. In the lower part, such clear cut distinction is not anatomically possible. The abdominal cavity is actually the superior portion of the larger abdominopelvic cavity that stretches between the thoracic diaphragm (the diaphragm muscle mentioned above) and the pelvic diaphragm (formed by the muscles related to the pelvic floor). The abdominal cavity, as such does not have a floor and is continuous with the pelvic cavity (which is the inferior portion of the abdominopelvic cavity). The superior pelvic aperture (pelvic inlet) is the dividing landmark between the two cavities. There is no physical separation, but only an arbitrary division exists at this landmark. It is also for the same reason that some authorities prefer to include the pelvis in abdomen.

The abdominal cavity (also called the ***cavum abdominis***) houses several important organs. Due to the unique positioning of the roof, the upper abdominal organs gain some osseofibrous protection. The diaphragm that forms the roof is arched superiorly. It projects into the thoracic space under normal circumstances. Because of this projection, the upper abdominal cavity is actually protected by the lower parts of the thoracic cage. Viscera like the liver, stomach and some parts of kidneys are well inside this protective cage.

As already noted, the abdominal cavity has no proper floor. However, some of the lower abdominal organs derive protection from yet another anatomical uniqueness that occurs at the level of the pelvic inlet. The pelvic inlet is the dividing line between the abdominal and the pelvic cavities. Superior to the inlet, some portions of the pelvic girdle are prolonged up and contribute to the formation of what is called the ***greater*** or ***false pelvis***. The ilial portions of the pelvic girdle expand upwards and laterally to form bony guards on either side. Some of the lower abdominal viscera like the lower coils of ileum, caecum, appendix and pelvic colon remain protected within this partial bony framework. It is only the viscera placed in the mid-abdominal cavity that are at risk.

REGIONS OF ABDOMEN (FIG. 12.1)

With several viscera remaining inside, the anterior abdominal wall is the door of a treasure house to the clinician. The door is as important and significant as the treasure house itself! The clinician attempts to identify the inner contained viscera through specific parts or locations of the anterior abdominal wall. In such an attempt, several methods have been used to demarcate specific regions of the abdomen.

The most widely used method divides the anterior abdominal wall into nine regions by using two vertical and two transverse (together the four cardinal planes of abdomen) planes. The two vertical planes are the ***right*** and ***left midclavicular planes***. Each midclavicular plane (or line as it is drawn on the anterior body wall) passes from the midpoint of the corresponding clavicle to the midinguinal point of the same side. This line is approximately 9 cm right or left from the midline. The two transverse planes are the transpyloric plane and the transtubercular plane.

The ***transpyloric plane*** is marked midway between the superior border of manubrium sterni and the pubic symphysis. This plane cuts through the L1 vertebra posteriorly. In the supine position, it transects the pylorus of the stomach and hence its name. In the standing position, the pylorus is usually at a slightly lower level (as all viscera tend to sag due to gravitational pull). In addition to the pylorus, the transpyloric plane also transects other important structures. These are the fundus of gallbladder, neck of pancreas, origin of superior mesenteric artery, commencement of portal vein, root of mesentery, duodenojejunal junction and the hila of kidneys. The plane therefore, is a 'landmark of assistance and compassion' to an operating surgeon and has been dubbed the 'key plane' of the abdomen precisely for this reason.

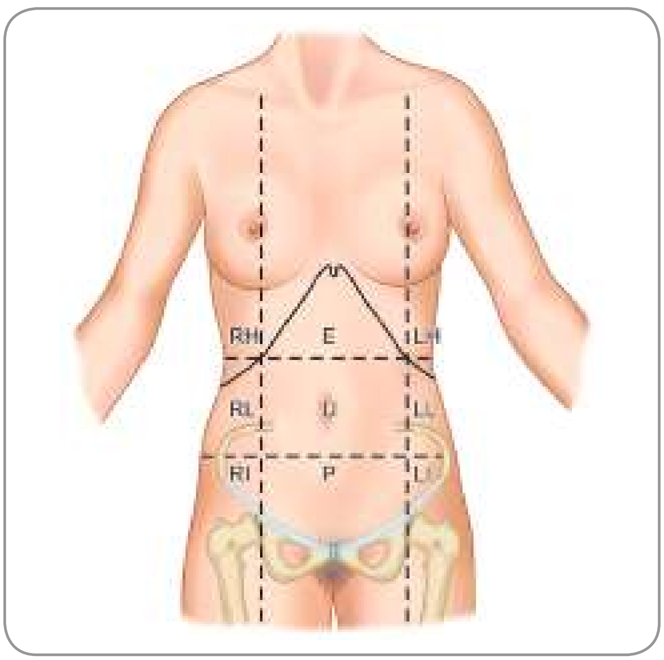


Fig. 12.1: Regions of abdomen

Key: E. Epigastric region **U.** Umbilical region **P.** Pubic region **RH/LH.** Right/Left hypochondriac region **RL/LL.** Right/Left lateral region **RI/LI.** Right/Left inguinal region

The ***transtubercular plane*** passes through the tubercles of the iliac crests and the body of L5 vertebra. It can be placed by marking the tubercle of the iliac crest approximately 5 cm behind the anterior superior iliac spine.

The four lines together mark nine regions of the abdomen. The midline (unpaired) regions from above downwards are:

- ***Epigastric region (regio epigastrica):*** This region is also called the ***epigastrium***; upper central region approximately marked between the two limbs of the costal margin.
- ***Umbilical region (regio umbilicalis):*** Central region around umbilicus.
- ***Pubic region (regio pubica):*** This region is also called the ***hypogastrium***; lower central region below the umbilicus and above the pubic symphysis.

On the right and the left sides, three paired regions are marked out. These are:

- ***Right and left hypochondriac regions*** (***regio hypochondriaca):*** It is also called the hypochondrium; upper right and left lateral regions which overlie the costal cartilages; named after this relationship to the costae (hypo=below, chondrium=costae).
- ***Right and left lateral regions*** (***regio lateralis abdominis):*** The lateral regions of the abdomen situated on each side of the umbilical region. Sometimes, these regions are referred to as the 'flank regions' of the abdomen. Though the name 'flank' appears to indicate their lateral position, it is preferable not to call / label these regions as the flank regions because the term is anatomically reserved for the lumbar region (or the region lumbalis) that lies on either side of the vertebral region between the rib cage and the pelvis. It can be understood that the lateral region of the abdomen merges imperceptibly with the lumbar region of its same side and hence this overlap in nomenclature.
- ***Right and left inguinal regions (regio inguinalis):*** It is also called the inguen; the region topographically related to the inguinal canal and lying lateral to the pubic region. It is sometimes (and colloquially) referred to as the 'groin'; this term is extremely ambiguous because it merely indicates the skin crease at the junction of the thigh and the trunk.

It can be seen that anatomically and arithmetically, the four lines divide the anterior abdominal wall into nine regions. However, study of the abdomen will not be complete without a study of the external genitalia which lie immediately below the inferior limit of the anterior abdominal wall. It is all the more important that a clinical examination of the abdomen will not be complete without an examination of the external genitalia (especially in the male). The structures of the external genitalia (more so in the male) are intimately connected to the structures in the abdominopelvic cavity or structures in the abdominal wall and are very often involved in pathologies of the latter. Hence, ***the urogenital region or triangle (regio urogenitalis—the anterior portion of the perineum) that contains the external genitalia (and the openings of the urethra in males and urethra and vagina in females) is anatomically included as a region of the abdomen***. A student of anatomy is expected never to forget the fact that the abdominal regions (as marked on the ventral body wall) are ten in number and not nine. The total of ten is derived by adding the urogenital region to the earlier count of nine regions marked by the four cardinal planes.

OTHER PLANES

Instead of the two transverse planes often used, some clinicians may prefer to use two other planes. One is the ***subcostal plane*** that passes through the tenth costal cartilage on either side. The other is the ***interspinous plane*** that passes through the readily palpable anterior superior iliac spine on either side. These two planes are applied because they can be marked easily. Very often, they are used in a 'cross combination' with the two transverse planes of the cardinal four. Thus, the subcostal and transtubercular planes make a pair and the transpyloric and interspinous planes make the other.

QUADRANTS OF ABDOMEN (FIG. 12.2)

In times of hurry (emergency clinical situations or in areas where detailed and accurate examination may not be possible), four quadrants of the abdomen are readily recognized. Two planes, one verticals and one horizontal, are used for this purpose. The vertical plane is the ***standard median plane*** that divides the body into equal right and left halves. The horizontal (transverse) plane is the ***transumbilical plane*** that passes through the umbilicus and cuts the vertebral column at the level of the intervertebral disc between L3 and L4. The abdomen is subdivided into four quadrants, namely the ***right upper, left upper, right lower and left lower quadrants***. The system of quadrant recognition is clinically convenient because it is possible to 'allocate' organs to each of the quadrants (by using the knowledge of the location of the organs inside the abdominal cavity). Though a similar allocation can be done to the ten regions of the abdomen (a system that was meticulously adopted until recently and before the advent of hitech investigative procedures), allocation to the quadrants is easier and less demanding merely because of the larger size of the quadrants and their simple right and left divisions.

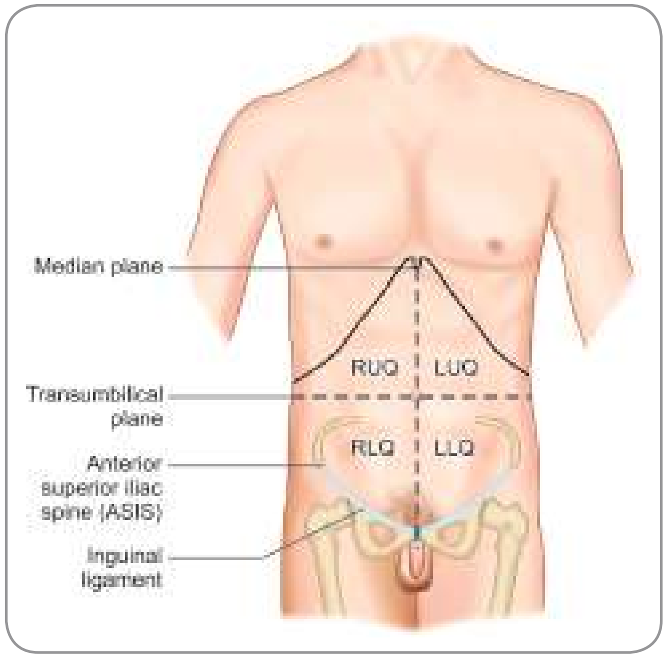


Fig. 12.2: Quadrants of abdomen

Key: RUQ. Right upper quadrant **RLQ.** Right lower quadrant **LUQ.** Left upper quadrant **LLQ.** Left lower quadrant

SURFACE FEATURES AND SIX-PACK ABDOMEN

The anterior abdominal wall presents certain important and well recognized surface features. The ***umbilicus*** (also called the navel, omphalos or belly button; Latin. Umbilikos=navel) is a marked feature. The xiphoid process (also called the ensiform cartilage) of the sternum can be easily palpated on the midline at the point of bifurcation of the costal margin. Extending from the xiphoid to the pubic symphysis on the midline is a faint line called the ***linea alba***; this line represents the actual linea alba (white raphe) of the musculoaponeurotic anterior abdominal wall on the surface. In muscular individuals, it can be seen as a well marked longitudinal groove. On either side of the linea alba, another faint groove can be made out in some (especially muscular) individuals. This is the ***linea semilunaris*** (or the linea semilunare) indicating the lateral border of the rectus abdominis muscle. In addition to these longitudinal, vertical lines, three pairs of transverse lines can also be made out. These are lines produced by the presence of tendinous intersections in the muscular substance of rectus abdominis. They are (usually) found (from above downwards) at the level of the xiphoid process, at the level of umbilicus and at a midlevel between the two. Additional transverse lines may be seen immediately above or below the level of umbilicus but are rare.

Added Information

Right Superior Quadrant
- Right lobe of liver
- Gallbladder
- Pyloric part of stomach
- First, second and third parts of duodenum
- Head of pancreas
- Right kidney and right suprarenal
- Right colic flexure
- Right portion of transverse colon
- Superior part of Ascending colon

Right Inferior Quadrant
- Caecum and Inferior part of ascending colon
- Vermiform appendix
- Ileum
- Right ovary and fallopian tube
- Abdominal part of right ureter
- Abdominal part of right spermatic cord
- Uterus (if enlarged)
- Completely filled urinary bladder

Left Superior Quadrant
- Left lobe of liver
- Spleen
- Most of stomach
- Jejunum and ileum
- Body and tail of pancreas
- Left kidney and left suprarenal
- Left colic flexure
- Left portion of transverse colon
- Superior part of descending colon

Left Inferior Quadrant
- Inferior part of descending colon
- Sigmoid colon
- Left ovary and Fallopian tube
- Abdominal part of left ureter
- Abdominal part of left spermatic cord
- Uterus (if enlarged)
- Completely filled urinary bladder

The concept of a six-pack abdomen has evolved by noticing the presence of the linea alba, linea semilunaris and the three pairs of transverse lines (collectively called the ***lineae transversae***). In muscular and well exercised individuals, these lines are well seen (marked as grooves) and the muscular masses between them stand out prominently. With a midline groove and three pairs of transverse grooves, six packs (three pairs) of muscle masses stand out. The two other vertical grooves provide the lateral boundaries for these packs and enhance their prominence. The overall picture has rendered itself to a fanciful (and much coveted) concept of the six-pack abdomen.

FUNCTIONAL SIGNIFICANCE OF THE ANTEROLATERAL ABDOMINAL WALL

As already seen, the anterolateral abdominal wall provides support and compactness to the contained viscera. It is the muscular force generated by this wall that keeps the viscera in position and in containment. The tone of the component muscles are important in providing for the force required to maintain the erect posture of the human. Gravitational pull tends to act upon the viscera and other contained structures thereby making them sag down. The muscles of the anterolateral wall, by their contraction, counter this gravitational pull and keep the abdomen and its contents in place. When the abdominal cavity enlarges beyond a level, the wall is not able to efficiently perform this regulatory function and the abdominal cavity sags down (seen as the sagging paunch in obesity). As a consequence, the lumbar vertebral column also undergoes changes. When the abdominal distension is temporary and reversible (as in the case of pregnancy), most of these changes can be rectified by appropriate exercise and therapy.

SEROUS LINING OF THE ABDOMINAL CAVITY AND PLACEMENT OF ABDOMINAL STRUCTURES

The abdominal cavity is a coelomic cavity. It is lined by a serous membrane called the ***peritoneum*** like the other coelomic cavities which are lined by their respective serous membranes. However, due to the presence of several viscera and their complicated arrangement within the cavity, the initial uncomplicated disposition of the 'lining' also gets complicated.

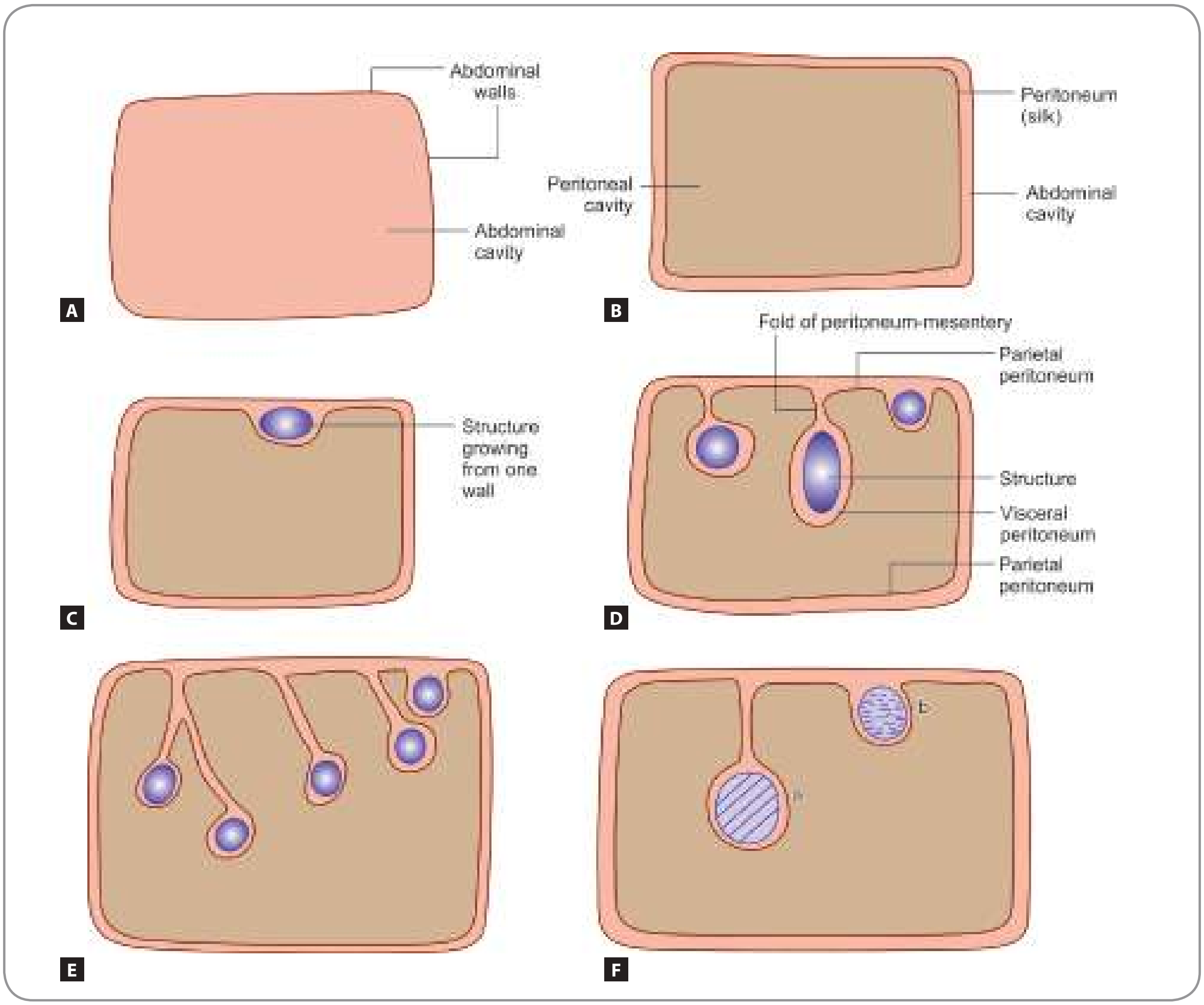
A simple, but clear understanding of the peritoneum can be had from a study of the development of the abdominal cavity and the peritoneum.

The abdominal cavity, in the initial stages of development, can be likened to a simple box (Fig. 12.3A). This box has a silk lining. The silk lining is the peritoneum or to be more precise, the peritoneal bag. It can now be realized that the box has a cavity of its own and within this cavity is the silk bag. The silk bag also has a cavity of its own. Since the silk bag is almost occupying the entire volume of the box, the 'true' cavity of the box is obscured (Fig. 12.3B). In other words, the 'true' cavity of the box is now a narrow space largely obscured by the 'filling' cavity of the silk. To draw parallel to the metaphors, the box is the abdomen and the true cavity of the box, the abdominal cavity. The silk is the peritoneum and the cavity of the silk is the peritoneal cavity.

The picture does not remain so simple for long. Structures (including the viscera) are developing within the abdominal cavity. In consonance with embryological lengthening and folding, most of these structures develop in relation to the posterior wall (though some of them migrate to other locations later). To go back to our 'box' description, something grows from one of the walls of the box and projects into its cavity. In the process of doing so, the growing structure pushes into the silk bag. This process of 'pushing' is called invagination (forming an internal sheath; in=internal/inner, vagina=sheath, vagination=sheath formation). The silk is pushed away from the wall of the box.

As both expansion of the structure and invagination into the peritoneum proceed further, the picture changes to what is shown in Fig. 12.3C. The structure now appears to be suspended from the wall of the box by a double layered fold of silk; the silk itself is subdivided into two portions: one lining the box and another surrounding (or covering) the structure; the cavity of the box is expanded and enlarged in part and the cavity of the silk is reduced. Therefore, the picture within the developing cavity is as follows:

- The (developing) viscus or structure appears to be suspended from the posterior wall by a double layered fold of peritoneum (Fig. 12.3D);
- This fold is given varied names according to the structure that it 'suspends'; mesentery if enteron (intestine) is suspended, mesogastrium if gaster (stomach) is suspended and so on (Fig. 12.3E);
- The peritoneum has been subdivided into two components—one lining the abdominal wall and called the parietal layer because it is in relation to the parietes



Figs 12.3A to F: A. Abdomen as a box **B.** Abdomen with peritoneal lining **C.** Growing structure pushes the lining – structure is outside peritoneum **D.** Scheme to show various arrangements likely to happen **E.** Scheme to show several structures; the peritoneal cavity is reduced **F.** Structure 'a' has mesentery, 'b' is retroperitoneal, but both 'a' and 'b' are extraperitoneal

or outer wall; the other covering or investing the viscus/ structure and called the visceral layer;
- The peritoneal cavity has been reduced in size (Fig. 12.F).

Development and expansion of more and more structures take place. Pressure dynamics and spatial configuration within the available abdominal cavity keep changing. All these factors lead to the following:
- The peritoneal cavity is greatly reduced (as shown in Fig. 12.3D);
- No structure is actually present within the peritoneal cavity;
- Structures are actually present inside and within the abdominal cavity;
- Vessels to the viscera pass through the suspending folds of peritoneum;
- Spatial and pressure alterations cause the parietal layer of peritoneum to adhere to the body wall and the visceral layer to the viscus concerned; the adherence of the visceral layer to the viscus is greater and the visceral layer appears to be an integral part of the microstructure of the viscus concerned;
- Some folds of peritoneum may adhere to others.

From the aforementioned facts, it can well be understood that no structure is '***intraperitoneal'*** (present inside the peritoneal cavity). All the abdominal viscera are ***intraabdominal, but extraperitoneal***. The peritoneal cavity, in the adult, exists as a narrow reduced potential space containing few milliliters of peritoneal fluid. It is called ***potential*** because it has the capacity to expand and become larger if required. Such expansions occur as a result of fluid or pus accumulation within the peritoneal cavity. Some structures, as they develop from the posterior wall, remain predominantly attached to the wall itself. They, either do not invaginate into the peritoneum or partially invaginate. Therefore, they are clothed by peritoneum only on their anterior aspects (and sometimes the sides) (Fig. 12.3E). Such structures remain on the posterior aspect of the peritoneal cavity and are termed as ***retroperitoneal***.

Though the above terminologies are followed anatomically, clinical usage differs. Many clinical treatises tend to label abdominal structures as 'intraperitoneal'. This is because the structures appear to be 'inside' the peritoneal cavity when the abdominal cavity is opened during surgeries. However, it is essential to remember that such a state is only an 'appearance'. The cavity of any structure should be within the limits of its walls; the cavity of the peritoneum can be only within its walls.

Multiple Choice Questions

1. What is false about cavum abdominis?
   a. It has no floor
   b. It is the same as cavum peritonei
   c. It merges inferiorly with the cavum pelvis
   d. It projects under the thoracic cage

2. The lateral boundaries for the six packs of a six-pack abdomen is formed by:
   a. Linea alba
   b. Lineae transversae
   c. Lineae semilunares
   d. Mid clavicular lines

3. The subcostal plane passes through the:
   a. Ninth costal cartilage
   b. Tenth costal cartilage
   c. Eighth costal cartilage
   d. Eleventh costal cartilage

4. The prefix 'mes' in the names of folds of peritoneum like the mesentery indicates:
   a. Their middle position between the abdominal wall and the concerned viscus
   b. Their mesodermal origin
   c. Their capacity to fold many times
   d. Their embryonic tendency to transmit blood vessels

5. The tenth region of the abdomen is:
   a. None
   b. Xiphoid region
   c. Urogenital region
   d. The back

ANSWERS

1. b **2.** c **3.** b **4.** b **5.** c

Clinical Problem-solving

Case Study 1: A surgeon was to perform an abdominal surgery on one of his patients. As he was studying the radiographs of the patient prior to surgery, the surgeon noticed some changes in the position of the viscera in the radiographs. He cross checked with the patient if the X-rays were taken while the patient was standing or lying.
- What is your opinion about the question of the surgeon?
- What made him ask such a question?
- Of what major significance is this information?

(For solutions see Appendix).

Chapter 13

Bones and Joints of Abdomen

Frequently Asked Questions

- Write notes on: (a) Typical lumbar vertebra, (b) Sacrum.
- Write briefly about the features of sacrum.
- Add a note on the sacrotuberous and sacrospinous ligaments.
- Write notes on: (a) Sex differences in sacrum, (b) Sacroiliac joints.

BONES OF ABDOMEN AND PELVIS

The bones which belong exclusively to the abdomen and pelvis are the lumbar vertebrae, sacrum and coccyx.

OTHER BONES RELATED TO STRUCTURES IN THE ABDOMEN

- The inner surfaces of the hip bones are closely related to structures in the abdomen and pelvis.
- The lower ribs and costal cartilages give attachment to, and are related to, many structures in the abdomen.

DISTINGUISHING FEATURES OF TYPICAL CERVICAL, THORACIC AND LUMBAR VERTEBRAE

The structure of a typical vertebra has been described in Chapters 2 and 3 of this volume in section on thorax. The cervical, thoracic and lumbar vertebrae can be easily distinguished from each other by the following characteristics:

- The transverse process of a cervical vertebra is pierced by a foramen called the ***foramen transversarium***.
- The thoracic vertebrae bear ***costal facets*** for articulation with ribs. These are present on the sides of the vertebral bodies and on the transverse processes.
- A lumbar vertebra can be distinguished from thoracic and cervical vertebrae by the fact that it neither has foramina transversaria nor does it bear facets for ribs. It is also recognised by the large size of its body.

LUMBAR VERTEBRAE

Other name: Vertebrae lumbales.

There are five lumbar vertebrae in the body. Typical vertebrae share certain common features and hence can be described as a single entity. Every type of vertebra has a set of typical and atypical vertebrae. Among the lumbar vertebrae, the first to fourth are grouped as typical lumbar vertebrae. The fifth lumbar vertebra has different features and hence is called the atypical lumbar vertebra.

Typical Lumbar Vertebra

The vertebral bodies progressively increase in size from above downwards. They are, therefore, largest in the lumbar vertebrae. The body of a lumbar vertebra is oval in shape. The vertebral foramen is triangular (Fig. 13.1). The pedicles are thick and short, and are directed backwards and somewhat laterally (Fig. 13.1). The laminae are short and broad, but do not overlap each other. The spinous processes are large and quadrangular. They are more or less horizontal and have a thick posterior edge (Fig. 13.2).The articular facets of lumbar vertebrae are vertical. They are curved from side-to-side. The superior facets are slightly concave (Fig. 13.1) and are directed equally backwards and medially. The inferior facets are slightly convex, and are directed equally forwards and laterally (Fig. 13.2). The superior articular processes are further apart from each other in comparison to the inferior articular processes in the typical lumbar vertebrae. Each superior articular process of a lumbar vertebra bears a rough projection called the mamillary process on its posterior border. A small accessory process is present on the posteroinferior aspect of the root of each transverse process.

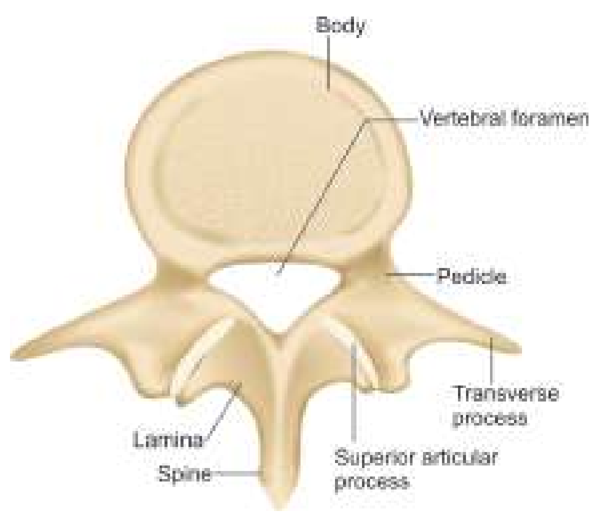


Fig. 13.1: Typical lumbar vertebra seen from above

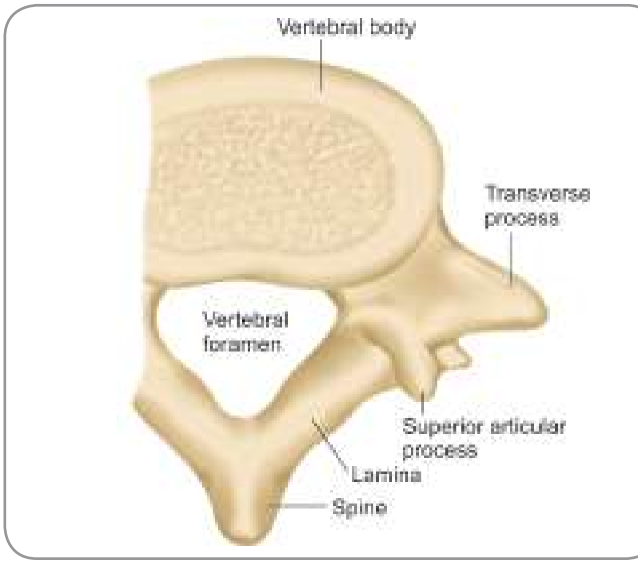


Fig. 13.3: Fifth lumbar vertebra seen from above

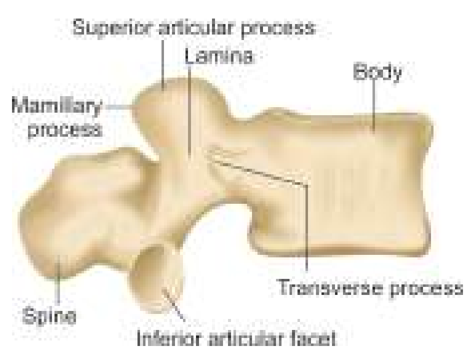


Fig. 13.2: Typical lumbar vertebra seen from the lateral side

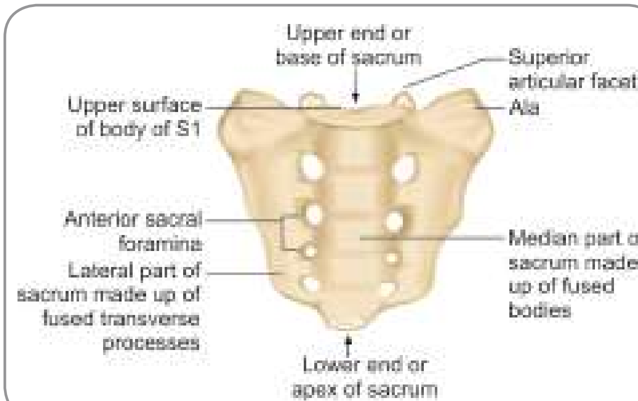


Fig. 13.4: Sacrum seen from the front

Atypical Lumbar Vertebrae

Fifth Lumbar Vertebra

Other name: Basilar vertebra.

The fifth lumbar vertebra is the largest of the lumbar vertebrae. In contrast to the small and tapering transverse processes of the typical lumbar vertebrae, the transverse processes of the fifth lumbar vertebra are very large. The superior and inferior articular processes are in the same line in the fifth lumbar vertebra. The spine is smallest with a rounded apex. These features form distinguishing characteristics of this vertebra (Fig. 13.3).

SACRUM

Other name: Vertebra magna.

The sacrum lies below the fifth lumbar vertebra. It is made up of the five sacral vertebrae which are fused together (Figs 13.4 and 13.5). It is wedged between the two hip-bones and takes part in forming the pelvis. As a whole, the bone is triangular. It has an upper end or ***base*** which articulates with the fifth lumbar vertebra and a lower end or ***apex*** which articulates with the coccyx. It has four surfaces, a concave ***anterior (or pelvic) surface***, a convex ***posterior or (dorsal) surface*** and right and left lateral surfaces which articulate with the ilium of the corresponding side.

View from Front

When viewed from the front (Fig. 13.4), the pelvic surface of the sacrum shows the presence of four pairs of ***anterior sacral foramina***. The first foramen is the largest and the fourth the smallest. The foramina separate the medial part of the bone from the lateral part. The medial part is formed by the fused bodies of the sacral vertebrae. The lateral part represents the fused transverse processes, including the costal elements. The anterior sacral foramina, seen on the pelvic surface, are continued into the substance of the bone and become continuous posteriorly with the ***posterior sacral foramina*** which open onto the dorsal surface. The canals connecting the anterior and posterior foramina open medially into the ***sacral canal*** which actually is a downward continuation of the vertebral canal.

View from Above

When viewed from above, the base of sacrum is seen. It is formed by the first sacral vertebra. It has a large oval body that articulates with the body of the fifth lumbar vertebra (Fig. 13.4). The body of the first sacral piece has a projecting anterior margin called the ***sacral promontory***. Behind the body of the sacrum is a triangular vertebral (or sacral) canal bounded by thick pedicles and laminae. Where the laminae meet, there is a small tubercle representing the spine. Arising from the junction of the pedicles and laminae are the superior articular facets which articulate with the inferior articular facets of the fifth lumbar vertebra. Lateral to the body, the superior surface of the lateral part called the ***ala*** is seen.

View from Behind

When the sacrum is viewed from behind (Fig. 13.5), the dorsal surface is seen. The medial and lateral parts are seen separated by four pairs of posterior sacral foramina. These foramina give passage to the dorsal rami of the sacral spinal nerves. The medial part of the dorsum of the sacrum is formed by the fused laminae of sacral vertebrae. The laminae of the fifth sacral vertebra (sometimes also of the fourth) are deficient leaving an inverted U-shaped or V-shaped gap called the ***sacral hiatus (Fig. 13.5)***. The midline is marked by a ridge called the ***median sacral crest*** on which four ***spinous tubercles*** (representing the spines) can be recognised. Just medial to the dorsal sacral foramina, four small tubercles which represent the fused articular processes are present. They collectively form the ***intermediate crest***. Lateral to the foramina, a prominent lateral sacral crest is formed by the fused transverse processes. The crest is marked by tubercles which represent the tips of transverse processes. The lower end of the bone (apex) bears an oval facet for articulation with the coccyx. At the sides of the sacral hiatus, there are two small downward projections called the ***sacral cornua***. They represent the inferior articular processes of the fifth sacral vertebra. They are connected to the coccyx by ligaments.

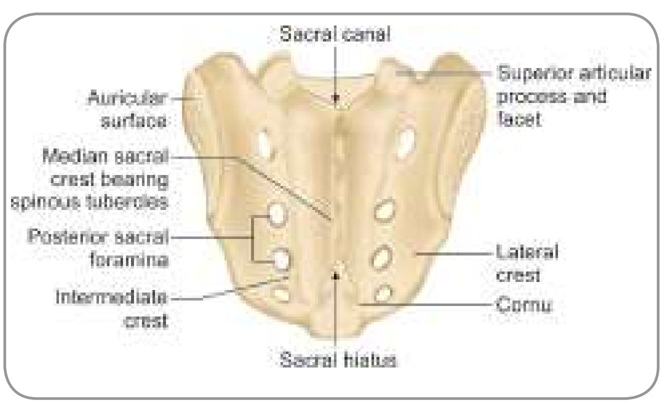


Fig. 13.5: Sacrum seen from behind

View from Side

When the sacrum is viewed from the side, it can be seen that the pelvic aspect of the bone is concave forwards, while the dorsal aspect is convex backwards. The lateral surface bears a large L-shaped ***auricular area*** (or facet) for articulation with the ilium (it is so called because its shape resembles that of the auricle or pinna). It consists of a cranial limb present on the first sacral vertebra and a caudal limb that lies on the second and third sacral vertebrae. The area behind the auricular surface is rough and gives attachment to the strong ligaments which connect the sacrum to the ilium.

The attachments on the sacrum and its ossification are described below along with those of the coccyx.

Added Information

Sex Differences in the Sacrum

- The female sacrum is wider and shorter than that of the male. This is to be correlated with the fact that the female pelvis is also shorter and broader than the male pelvis.
- The forward concavity is more pronounced in the female.
- The auricular surface is shorter in the female.
- However, for practical purposes the sex of a given sacrum is most easily found out by examining the base.
  - In the female, the transverse diameter of the body is approximately equal to the width of the ala.
  - But in the male, the diameter of the body is distinctly larger than that of the ala.

COCCYX

Other names: Caudal vertebra, tail vertebra.

The coccyx consists of four rudimentary vertebrae fused together. It has pelvic and dorsal surfaces. The base or upper end has an oval facet for articulation with the apex of the sacrum (Fig. 13.6). Lateral to the facet, there are two cornua that project upwards and are connected to the cornua of the sacrum by ligaments. The first coccygeal vertebra has rudimentary transverse processes. The remaining vertebrae are represented by nodules of bone.

Attachments on the Sacrum and Coccyx

Muscular Attachments (Figs 13.7 and 13.8)

- ***Iliacus*** arises from the anterolateral part of the upper surface of the ala (or lateral part).

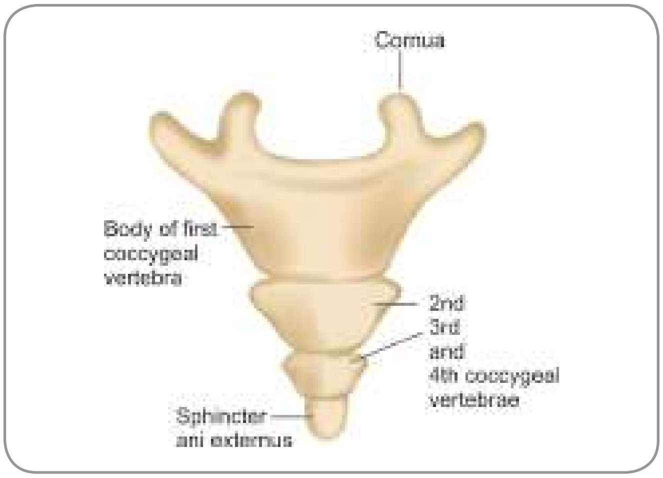


Fig. 13.6: Coccyx seen from the front

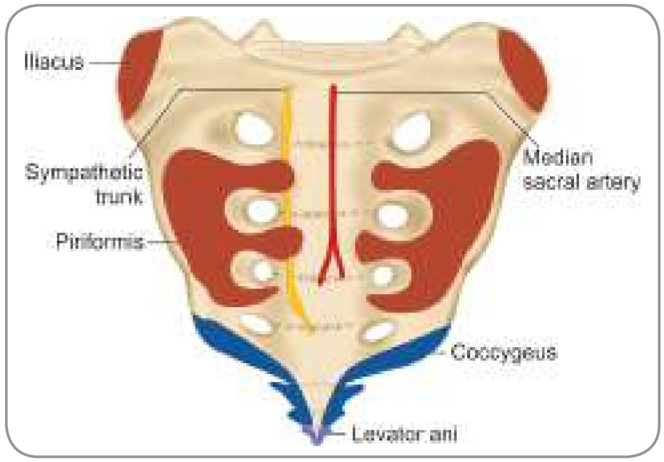


Fig. 13.7: Attachments on the pelvic aspect of the sacrum and coccyx. Some related structures are also shown

- ***Piriformis*** arises from the pelvic surface. The medial part of the origin is in the form of three digitations which arise from the areas between the sacral foramina (Fig. 13.7).
- ***Coccygeus*** is inserted into the lateral side of the pelvic aspect of the last piece of sacrum and to coccyx (Fig. 13.7).
- ***Levator ani*** is inserted into the sides of the lower two segments of the coccyx (Fig. 13.7).
- ***Gluteus maximus*** arises from the lateral margin of the lowest part of sacrum, and that of coccyx (Fig. 13.8).
- ***Erector spinae*** has a linear U-shaped origin from the dorsal aspect of sacrum. The medial limb of the 'U' is attached to the spinous tubercles, and the lateral limb to the transverse tubercles (Fig. 13.8).
- ***Multifidus*** arises from a large area within the U-shaped origin of the erector spinae (Fig. 13.8).

Ligamentous Attachments

- Ligaments of the joints between the fifth lumbar vertebra and the sacrum correspond to those of other intervertebral joints.
- The area around the auricular surface gives attachment to the ventral, dorsal and interosseus ligaments of the sacroiliac joint.
- The ***iliolumbar ligament*** is attached to the lateral part of the ala.

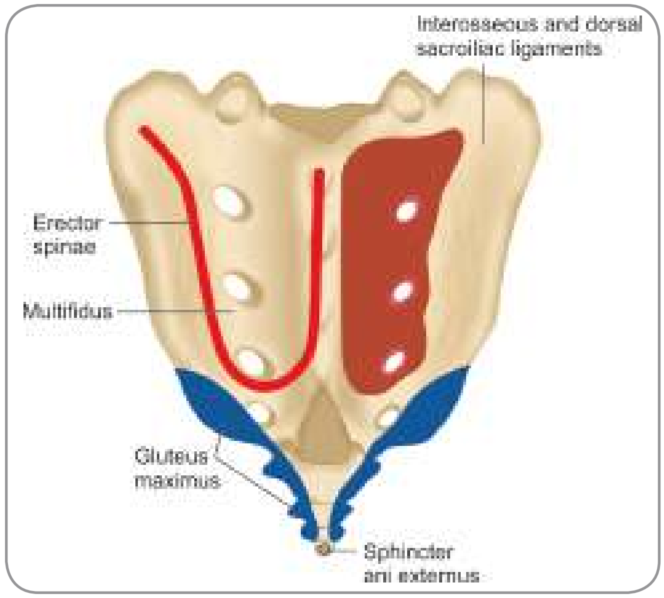


Fig. 13.8: Attachments of muscles on the posterior aspect of the sacrum and coccyx

- The ***sacrotuberous ligament*** is attached to the lower lateral part of the dorsal surface of the sacrum.
- The ***sacrospinous ligament*** is attached to the lower part of the lateral margin of the sacrum and to the adjoining lateral margin of the coccyx.

Added Information

Important Relations of Sacrum

- The rectum is in contact with the ventral surface of the 3rd, 4th and 5th pieces of sacrum.
- The ventral surfaces of the first three pieces of sacrum are covered by peritoneum and give attachment to the sigmoid mesocolon.
- Deep to the peritoneum and rectum, the ventral surface is crossed by the right and left sympathetic trunks, the median sacral vessels, the right and left lateral sacral vessels, and the superior rectal vessels.
- The ala is covered by the psoas major muscle and is crossed by the lumbosacral trunk.
- The sacral canal contains the cauda equina, the spinal meninges and the filum terminale. The subarachnoid and subdural spaces end at the level of the middle of the sacrum.
- The ventral and dorsal sacral foramina give passage to the corresponding rami of sacral nerves.

JOINTS OF ABDOMEN

INTERVERTEBRAL JOINTS

The joints between the lumbar vertebrae are similar to the typical intervertebral joints. These have been described in Chapter 4.

LUMBOSACRAL JOINT

This joint is similar to an intervertebral joint. However, because of the large size of the vertebral bodies involved, the intervertebral disc is thick and large. It is deepest anteriorly. The fifth lumbar vertebra and the pelvis are connected by two additional ligaments, namely the iliolumbar ligament and the lumbosacral ligament. The ***iliolumbar ligament*** connects the tip of the transverse process of the fifth lumbar vertebra to the posterior part of the iliac crest. The ***lumbosacral ligament*** is attached above to the inferior margin and anterior aspect of the transverse process (of fifth lumbar vertebra). Below it is attached to the sacrum near the anterior sacroiliac ligament.

PUBIC SYMPHYSIS

The two pubic bones are united in front at the ***pubic symphysis***. This is a secondary cartilaginous joint. Such cartilaginous joints are permanent structures which do not disappear with age. They are also called ***symphyses***. The bone ends forming the joint are covered by a thin layer of hyaline cartilage. The two layers of hyaline cartilage are united by an intervening layer of fibrocartilage.

SACROILIAC JOINTS

The sacrum articulates on each side with the corresponding ilium forming the right and left sacroiliac joints. These are synovial joints. The iliac and sacral surfaces are both shaped like the auricle (pinna) and are, therefore, called ***auricular surfaces***. The surfaces are covered by cartilage, but because of the presence of a number of raised and depressed areas the joint allows little movement. The capsule of the joint is attached around the margins of the articular surfaces. It is thickened in its anterior part to form the ***ventral sacroiliac ligament***. The main bond of union between the sacrum and ilium is, however, the ***interosseous sacroiliac ligament*** that is attached to the rough areas above and behind the auricular surfaces of the two bones. The posterior aspects of the sacrum and ilium are connected by a strong ***dorsal sacroiliac ligament*** that covers the interosseous ligament from behind. The stability of the sacroiliac joints is important as body weight is transmitted from the sacrum to the lower limbs through them.

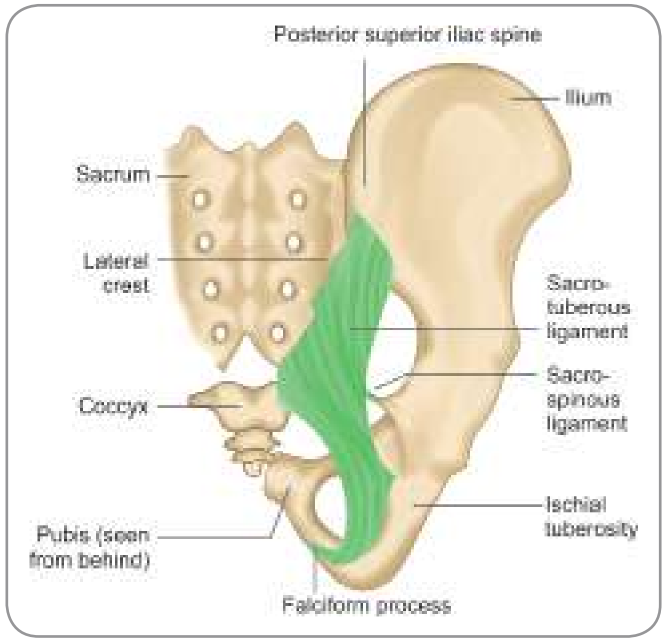


Fig. 13.9: Sacrotuberous and sacrospinous ligaments

Two other ligaments which connect the sacrum to the hip-bone are the sacrotuberous and the sacrospinous ligaments. These ligaments are seen in the gluteal region (Fig. 13.9).

SACROTUBEROUS LIGAMENT

The sacrotuberous ligament is large and strong. It has a broad upper medial end and a narrower lower lateral end. The upper end is attached (from above downwards) to the posterior superior and posterior inferior iliac spines, the lower part of the posterior surface of the sacrum (transverse tubercles) and the lateral margin of the lower part of the sacrum and the upper part of the coccyx (Fig. 13.9). Its lower end is attached to the medial margin of the ischial tuberosity. Some fibres which continue onto the ramus of the ischium constitute the ***falciform process***.

SACROSPINOUS LIGAMENT

The sacrospinous ligament is attached medially to the sacrum and coccyx and laterally to the ischial spine (Fig. 13.9).

Clinical Correlation

Joints of Pelvis

These are important joints as they are stretched during pregnancy and parturition. During pregnancy, the ligaments of joints of pelvis are softened by the action of hormones (oestrogen, progesterone, relaxin) produced by the ovaries and the placenta. Softening of the ligaments increases the range

contd...

Clinical Correlation ***contd…***

of movement permitted at the sacroiliac joint and this facilitates the passage of the head of the foetus through the pelvis. However, softened ligaments render the sacroiliac joint more liable to strain and the effects of such strain may persist even after the end of pregnancy. As ligaments tighten after pregnancy, the joint may sometimes get locked in an abnormal position. This is called subluxation of the joint. Strain in the sacroiliac joint leads to pain over the region of the joint. The pain may also radiate into the upper part of the thigh.

Dimensions of the Female Pelvis and their Importance in Obstetrics: During childbirth, the foetus has to pass through the true pelvis. The largest part of the foetus is the head and for smooth passage of the foetus, the dimensions of the true pelvis have to be large enough for the foetal head to be able to pass through it. In cases where the passage is not large enough, a condition called ***cephalopelvic disproportion results***. One of the important aspects of antenatal care is to examine the expectant mother that her pelvis is of normal size. Various methods have been used for this purpose as follows:

- ***External pelvimetry:*** In this procedure, an attempt is made to judge to size of the birth canal by making measurements between bony landmarks of the pelvis which can be felt on the surface of the body. They include:
  - The distance between the two anterior iliac spines (***interspinous diameter***);
  - The distance between the outermost points on the right and left iliac crest (***intercristal diameter***); and
  - The anteroposterior distance between the lowest sacral spine and the pubic symphysis (***external conjugate***).

  However, experience has shown that information provided by such measurements is of little value and the procedure is of historical importance only.
- ***Internal pelvimetry:*** A better estimate of pelvic dimensions can be made by trying to palpate some features of the pelvis by fingers introduced into the vagina (vaginal examination). Such examination can be done most usefully in the later weeks of pregnancy as, by this time, the actions of hormones make the tissues of the pelvis much softer than normal. The ligaments are also affected and the joints are less rigid. However, the procedure requires considerable experience.
- During vaginal examination, the obstetrician tries to estimate the side to side dimension of the pelvis by feeling for the width and shape of the pubic arch, and the distance between the right and left ischial tuberosities. To get an estimate of the anteroposterior diameter, a finger is placed against the sacral promontory and the distance of this point from the pubic symphysis is estimated. This measurement that is referred to as the ***diagonal conjugate*** is normally at least 11.5 cm. The actual anteroposterior diameter at the inlet of the pelvis (***true conjugate***) can be estimated from the diagonal conjugate as the former is 1.5 to 2 cm less than the diagonal conjugate. Apart from the above, the obstetrician tries to palpate the lateral and posterior walls of the bony pelvis to find out if the curvatures are normal.

Abnormalities in shape of the pelvis: The shape of the pelvis can be congenitally abnormal, but most abnormal pelvis result from lack of adequate nutrition. The shape of the pelvis can also become abnormal after injury. In the typical female pelvis, the pelvic inlet is oval and the transverse diameter is slightly larger than the anteroposterior diameter. This is referred to as the gynaecoid type of pelvis (or as the mesatipellic pelvis). In contrast to the female pelvis, the inlet of the male pelvis tends to be triangular so that the greatest transverse diameter is placed more posteriorly than in the female. When a female pelvis resembles the male pelvis, it is described as **android** (or **brachypellic**).

In anthropoid apes, the anteroposterior diameter of the pelvis is clearly greater than the transverse diameter. Such a condition is sometimes seen in the female pelvis that is then referred to as being of the ***anthropoid*** type. An anthropoid pelvis tends to be long and narrow. In some pelves, the transverse diameter of the inlet is normal, but the anteroposterior diameter is small (so that the pelvis appears to be flattened from front to back). This is referred to as the ***platypelloid*** type of pelvis.

It is important to note that the different types of pelvis described above are to be regarded as variants of the normal female pelvis and are compatible with normal childbirth provided the dimensions are adequate. The pelvis is gynaecoid only in about 41% of women, android in about 33%, and anthropoid in about 24%. The platypelloid type is a rarity. Absolute dimensions are more important than relative proportions of various dimensions. In some cases, the pelvis may have a normal shape, but its dimensions may be small. Such a ***contracted pelvis*** is not compatible with normal labour.

Fractures of pelvis: These are not common. They may occur through the superior or inferior ischiopubic ramus, near the junction of the pubis and ischium (when they may involve the acetabulum), or the lateral part of the ilium. Isolated fractures of one part of the pelvis are usually not serious as long as the ring formed by the two hip bones and sacrum is not disrupted. Disruption of the ring occurs when it is broken (or dislocated) at two points (e.g., fracture of both ischiopubic rami combined with dislocation at the sacroiliac joint). When disruption occurs, there can be injury to the urinary bladder, the urethra, the rectum, or the vagina. Injury to a large artery in the pelvic wall can cause severe bleeding. In serious disruption of the pelvis, there may be permanent damage to nerves of the lumbosacral plexus. When a fracture of the pelvis involves the acetabulum, it can eventually lead to osteoarthritis at the hip joint. Extremely strong contraction of muscles (in competitive sports) can tear off a tendon from its attachment along with a small piece of bone. The anterior superior and anterior inferior iliac spines can be torn off. These are called ***avulsion fractures***.

Multiple Choice Questions

1. The lateral part of the sacrum represents the
- a. Fused vertebral bodies
- b. Fused transverse processes without costal elements
- c. Fused transverse processes with costal elements
- d. Fused costal elements

2. The mamillary process is found on the posterior border of the
- a. Superior articular process
- b. Inferior articular process
- c. Spinous process
- d. Transverse process

3. The atypical of the lumbar vertebrae is the
- a. 5th lumbar
- b. 1st lumbar
- c. 3rd lumbar
- d. Variable

4. The falciform process of the sacrotuberous ligament continues on the
- a. Ischial ramus
- b. Lateral part of sacrum
- c. Ischial spine
- d. Tendon of Biceps femoris

5. The articular surfaces of a joint are also called the auricular surfaces. Which joint is that?
- a. Lumbosacral joint
- b. Sacroiliac joint
- c. Sacropubic joint
- d. Pubic symphysis

ANSWERS

1. c **2.** a **3.** a **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A pregnant mother is diagnosed with cephalopelvic disproportion.
- ❑ What is cephalopelvic disproportion?
- ❑ How is the condition diagnosed/confirmed?
- ❑ What will the expected problem/complication?

(For solutions see Appendix).

Chapter **14**

Preview of Abdominal Cavity and Anterior Abdominal Wall

Frequently Asked Questions

- Write notes on: (a) Rectus sheath, (b) Inguinal ligament, (c) Superficial fascia of abdomen.
- Discuss the rectus sheath in detail.
- Write briefly on: (a) Inguinal canal, (b) Linea alba, (c) Lacunar ligament.

ABDOMINAL CAVITY AND ITS EXTENT

The abdomen is the region of the trunk below the diaphragm. It consists an upper part, the ***abdomen proper*** and a lower part, the ***true pelvis***, which are continuous at the plane of the inlet of true pelvis (Figs 14.1 and 14.2).

- ***Superiorly***, the abdominal cavity is bounded by the diaphragm, which separates it from the cavity of the thorax. As the domes of the diaphragm reach much above the level of the costal margin, a considerable part of the abdominal cavity lies deep to the thoracic cage.
- ***Inferiorly***, the abdominal cavity extends into the false pelvis (i.e., the part of the pelvis above the pelvic brim). It is directly continuous with the cavity of the true pelvis.

The gluteal region lies behind the lower part of both the abdominal cavity and the pelvic cavity.

REGIONS OF ABDOMEN

The relationship of the abdominal viscera to the surface of the body is of considerable importance. As the anterior and lateral walls of the abdomen are devoid of skeletal landmarks (except at their upper and lower ends), reference has to be made to some imaginary planes.

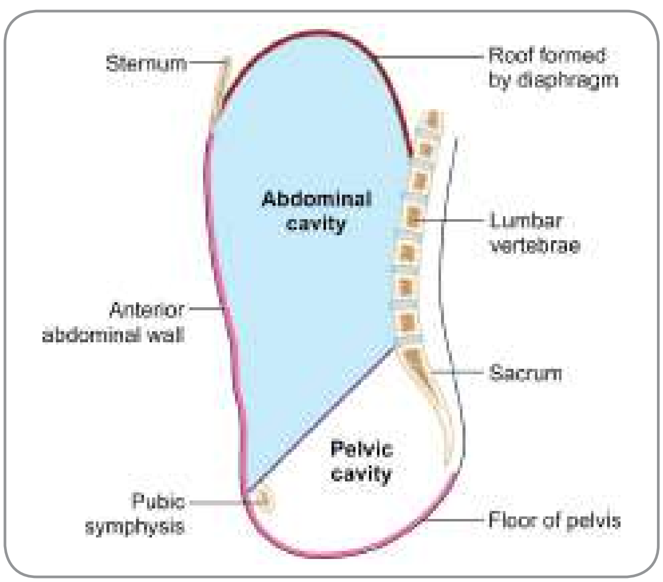


Fig. 14.1: Schematic sagittal section to show extent and walls of the abdominal cavity

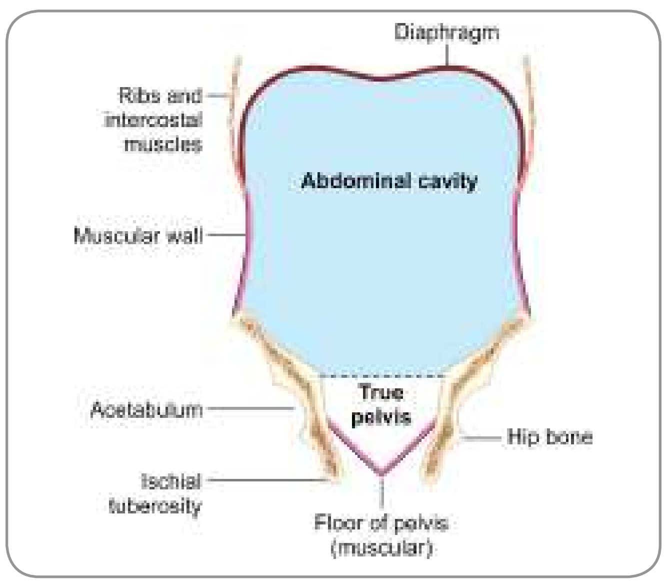


Fig. 14.2: Schematic coronal section through abdominal cavity to show its extent and its walls

The anterior aspect of the abdomen, therefore, is divided into nine regions by using two transverse and two vertical planes (Fig. 14.3).

- The superior transverse plane is the ***transpyloric plane***. It lies midway between the upper border of the manubrium sterni (suprasternal notch) and the upper border of the symphysis pubis. It is roughly midway between the lower end of the body of sternum (not of xiphoid process) and the umbilicus or a hand's breadth below the lower end of the body of sternum. It passes through the lower part of body of L1 vertebra and cuts the costal margin at the tip of the ninth costal cartilage. Internally, this plane cuts across the pylorus and hence its name.
- The inferior transverse plane is the ***transtubercular plane***. It lies at the level of the tubercles of the iliac crests. The tubercles of iliac crests are prominences on the outer lip of each iliac crest about 5 cm behind the anterior superior iliac spines. It passes through the upper part of body of L5 vertebra. Since the plane cuts through the tubercles of the iliac crests, it has been called the transtubercular plane.
- The two vertical planes used for subdividing the abdomen into regions are the ***right*** and ***left lateral planes***. On the anterior aspect of the body, they are represented by the right and left lateral lines. The right and left lateral lines are commonly referred to as the ***midclavicular lines***.
  - The upper end of each line is at the midpoint between the medial and lateral ends of the clavicle.
  - Its lower end is midway between the anterior superior iliac spine and the pubic symphysis.

The upper limit of the abdomen demarcated by the diaphragm can be described to lie at the level of the lower end of the body of sternum. Similarly, the lower limits of the abdominal cavity are marked by the right and left inguinal ligaments. Keeping in mind the planes and limits defined above, the abdomen is divided into the following nine regions (Fig. 14.3):

- In the midline from above downwards:
  - ***Epigastrium*** (EPG),
  - ***Umbilical region*** (UMB),
  - ***Hypogastrium*** (HYG) which is also called the ***pubic region***.
- Lateral to the epigastrium (that is, on either side) are:
  - ***Right hypochondrium*** (RH),
  - ***Left hypochondrium*** (LH).
- Lateral to the umbilical region (that is, on either side) are:
  - ***Right lumbar region*** (RL)
  - ***Left lumbar region*** (LL). The lumbar regions are also called ***lateral regions.***

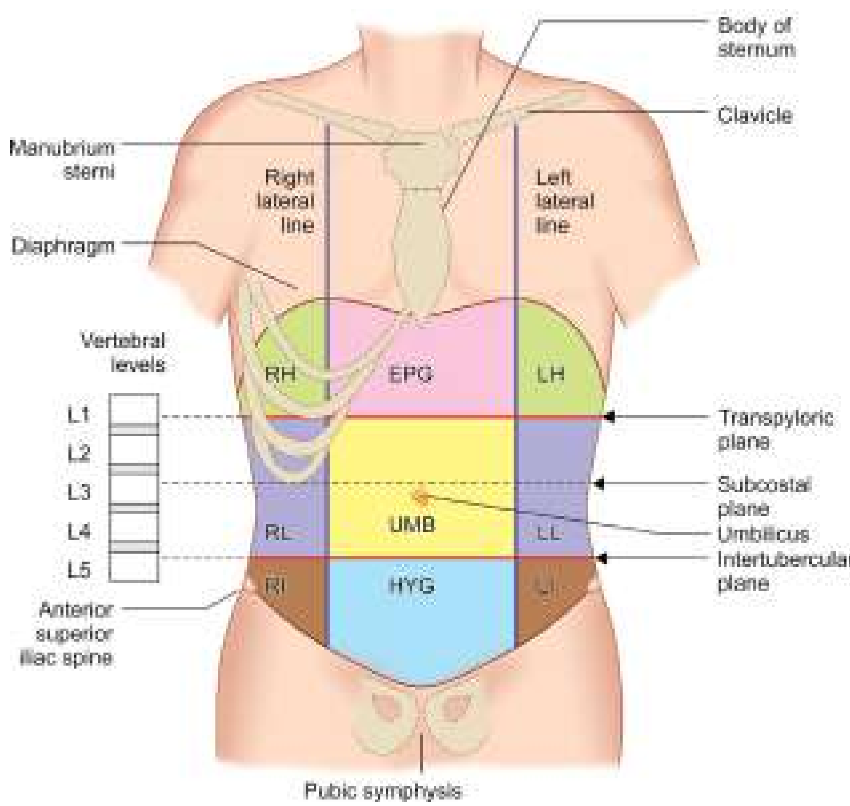


Fig. 14.3: Regions of the abdomen and the lines demarcating them

- Lateral to the hypogastrium (that is, on either side) are:
  - ***Right inguinal region*** (RI), also called the ***right iliac fossa***.
  - ***Left inguinal region*** (LI), also called the ***left iliac fossa***.
- Two additional planes are sometimes used. These are:
  1. The ***subcostal plane*** at the level of the lowest part of the costal margin formed by the tenth costal cartilage; this plane lies at the level of the upper part of body of L3 vertebra; some authorities use this plane (instead of the transpyloric) for dividing the abdomen into the regions mentioned above.
  2. The ***supracristal plane*** at the level of the highest points of the iliac crests; when drawn on the posterior surface of the body, this plane cuts the spine of L4 vertebra and is used as a guide to locate this spine.

In addition to the nine regions marked on the anterior abdominal wall, the external genital region in males is also included as a region of the abdomen. ***Thus, regions of abdomen number ten and not nine.***

Other Surface Markings Related to Abdomen

The midline of the anterior abdominal wall is marked by a slight groove. When skin over the midline is removed, a white line called the ***linea alba*** (Latin.albus=white) is seen.

When the rectus abdominis is made to contract (e.g., by asking a lying person to sit up), the lateral edge of the muscle is seen in the form of a curved line extending from the pubic tubercle below to the tip of the 9th costal cartilage above. This line is the ***linea semilunaris*** (so named because of its semilunar shape). Its junction with the costal margin at 9th costal cartilage lies at the level of the transpyloric plane.

The ***umbilicus*** is a prominent feature on the anterior abdominal wall, but is not a useful landmark because of variability in its position. In the healthy young adult, it usually lies at the level of the intervertebral disc between L3 and L4. The umbilicus marks the point at which the umbilical cord is attached during foetal life. The cutaneous nerve supply of skin at the level of the umbilicus is derived from the tenth intercostal nerve.

WALLS OF ABDOMEN

The anterior and posterior walls of abdomen can be studied by examining a transverse section through the abdominal cavity.

Structures forming the ***posterior abdominal wall*** are:

- In the median plane-the lumbar vertebrae,
- On each side of the vertebral bodies-***psoas major*** muscle,
- More laterally-***quadratus lumborum*** muscle.

The part of the abdominal wall extending from the midline in front, to the lateral edge of the quadratus lumborum is referred to as the ***anterior abdominal wall***. However, it is not confined to the anterior aspect of the abdomen, but covers the lateral aspect as well.

Structures forming the ***anterior abdominal wall*** are:

- On either side of the midline-***rectus abdominis muscle*** which runs vertically. This muscle is seen in transverse section in Figure 14.4.

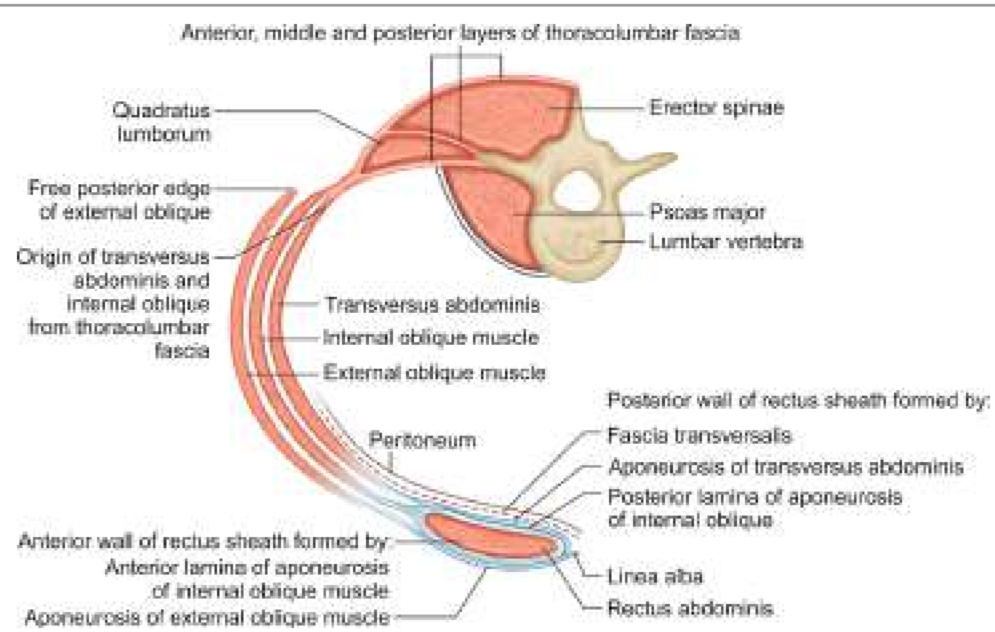


Fig. 14.4: Schematic transverse section through abdominal wall to show its layers

- Between the lateral edge of the rectus abdominis and the lateral edge of the quadratus lumborum , the anterolateral wall is made up of three layers of muscle. From outside to inside, these layers are formed by the ***external oblique***, ***internal oblique*** and ***transverse muscles of the abdomen***. These three are collectively referred to as the anterolateral muscles of the abdominal wall.
- The innermost layer of muscle is lined by a fascia called the ***fascia transversalis***. This fascia is lined on its inner aspect by the ***parietal peritoneum***, the two being separated by a layer of ***extraperitoneal fat***.

At the costal margin, the anterior abdominal wall becomes continuous with the thoracic wall. Hence, both the thoracic and abdominal walls have three layers of muscle. The external oblique muscle of the abdomen corresponds in position, and in the direction of its fibres, to the external intercostal muscle. The same is also true about the internal oblique muscle of the abdomen and the internal intercostal muscle. In the abdomen, the third layer is formed by the transverses abdominis muscle which is so called because its fibres run transversely. It corresponds to the transversus thoracis muscle in the thoracic cavity (although the fibres of latter's constituent parts do not run transversely).

The nerves and vessels in both thorax and abdomen lie between the second and third layers of muscles.

Superficial Fascia of Abdomen

The superficial fascia of abdomen consists of a single layer over a greater part. However, over the lower part of the anterior abdominal wall and over the perineum, the superficial fascia consists of two layers—a ***superficial fatty layer*** and a ***deeper membranous layer***.

Superficial Fatty Layer

Other names: Tela subcutanea, fascia of Camper.

The fatty layer corresponds to superficial fascia elsewhere in the body and continues below with the superficial fascia of the thigh. In the male, the superficial layer continues over the penis and scrotum, where it changes in character and becomes devoid of fat. It also contains some muscular fibres within it called the dartos muscle. From the scrotum, it continues backwards with the superficial fascia of perineum.

In females, it continues from the abdomen into the labia majora and perineum.

Deep Membranous Layer

Other names: Lamellar layer of abdominal fascia, fascia of Scarpa.

In the perineum, the deeper membranous layer is called the ***fascia of Colles***.

The deep layer is loosely connected by areolar tissue to the external oblique aponeurosis. In the median plane, it is tightly adherent to the linea alba and pubic symphysis and is extended over the penis to form the fundiform ligament. Superiorly, the membranous layer ends by merging with the fatty layer of the rest of the trunk. When traced downwards:

- A little lateral to the midline—it is fused to the body of the pubis. In the anterior part of the perineum, the membranous layer is attached to the pubic arch. The posterior edge of the fascia reaches the posterior border of the perineal membrane and fuses with it.
- Laterally, it passes into the upper part of the thigh across the inguinal ligament. However, the layer ends a short distance below the ligament by fusing with the deep fascia along a horizontal line extending laterally from the pubic tubercle. The line of fusion is called the ***Holden's line*** (Fig. 14.5).

Deep Fascia of Abdomen

The abdominal cavity is required to expand and contract with each respiration. It also expands when the stomach is full of ingested food. Apart from this, it is capable of expanding enormously in pregnancy or as a result of accumulation of fluid or because of the presence of a large tumour within it. Hence, unlike the limbs, the abdomen cannot be enclosed in a tight sleeve of deep fascia. Hence, deep fascia is absent over the front and sides of the abdomen.

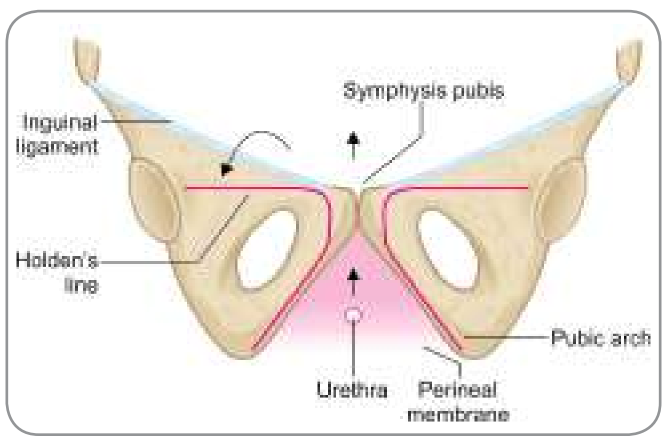


Fig. 14.5: Diagram to show lines along which the membranous layer of superficial fascia is firmly united to underlying structures (anterior view). Arrows indicate the path that can be taken by extravasated urine if the urethra is ruptured

Clinical Correlation

The attachments of the membranous layer of superficial fascia acquire significance in case of rupture of urethra in the perineum. In such a case, urine leaking out of the urethra passes into the space between the membranous layer and deeper structures. It cannot pass backwards beyond the perineal membrane because the membranous layer of fascia is fused to the posterior border of the perineal membrane. It cannot spread laterally into the thigh because of the attachment of the membranous layer to the ischiopubic rami. However, it can pass forwards over the scrotum, over the penis, and upwards over the pubic symphysis into the lower part of the anterior abdominal wall and can pass laterally over the lower part of the abdominal wall and can then pass downwards across the inguinal ligament into the thigh. Its further descent into the thigh is limited by the fusion of the membranous layer of superficial fascia to the deep fascia of thigh along the Holden's line.

ANTERIOR ABDOMINAL WALL

ANTEROLATERAL MUSCLES OF ABDOMINAL WALL

These are as follows (Table 14.1):

Table 14.1: Anterolateral muscles of abdomen

	Obliquus externus abdominis	Obliquus internus abdominis	Transversus abdominis
Direction of fibres	The fibres run downwards and forwards	The fibres run forwards and upwards (at right angles to externus)	The fibres run forwards
Origin	External surfaces and lower borders of 5th to 12th ribs	• Uppermost fibres from thoracolumbar fascia at the lateral border of the quadratus lumborum muscle • Middle fibres from the anterior two-thirds of the intermediate zone of the ventral segment of the iliac crest • Lowest fibres from the lateral two-thirds of deep aspect of grooved upper surface of inguinal ligament	• Upper fibres from inner aspect of lower 6 costal cartilages • Middle fibres from thoracolumbar fascia at lateral border of quadrates lumborum muscle • Lower fibres from anterior two-thirds of inner lip of ventral segment of iliac crest • Lowest fibres from upper grooved surface of lateral one-third of inguinal ligament
Insertion	• All fibres except those arising from the 11th and 12th ribs end in an extensive aponeurosis. The aponeurosis is attached to: – Xiphoid process – Linea alba – Pubic crest and pubic tubercle – Lateral to the pubic tubercle the aponeurosis has a free lower border that forms the inguinal ligament. This ligament is attached laterally to the anterior superior iliac spine • The fibres that arise from the 11th and 12th ribs are inserted into the anterior half of outer lip of iliac crest	• Fibres arising from thoraco lumbar fascia and the posterior part of iliac crest are inserted into lower border of lower three ribs • Fibres from anterior part of iliac crest and lateral part of inguinal ligament end in an aponeurosis. Its upper part is attached to the costal margin. Its lower part is attached to entire length of linea alba • Fibres from middle one-third of inguinal ligament are related to the inguinal canal. They first lie in front of the canal, then in its roof, and then behind the canal. Here the fibres join those of the transversus to form the conjoint tendon. This tendon is inserted into the pubic crest and pecten pubis	• Fibres end in aponeurosis which are inserted chiefly into linea alba • Lowest part of aponeurosis joins that of internal oblique to form conjoint tendon which is inserted into pecten pubis and pubic crest
Nerve supply	For all muscles—lower six thoracic nerves		
Action	• Support abdominal viscera • Increase intra-abdominal pressure that helps to expel contents of viscera (as in defecation, micturition, vomitting and child birth)		

Dissection

Make the following incisions:
- A vertical incision from the xiphoid process to the pubic symphysis in the anterior midline.
- A curved incision, first from the pubic symphysis to the pubic tubercle and then from the pubic tubercle to the anterior superior iliac spine along the fold of groin.
- A curved incision from the anterior superior iliac spine along the iliac crest atleast till the midaxillary line.
- A transverse incision from the xiphoid process to the midaxillary line.
- Carefully reflect the skin flap laterally. Identify the superficial fascia. Try to locate the cutaneous nerves and vessels. Then shift your attention to the muscles. Read the theory of these muscles before you start a dissection. Clean the fascia. Observe the external oblique muscle. See the direction of its fibres. Feel for the inguinal ligament. See if you can insinuate your fingers gently underneath the inguinal ligament. if possible, observe its 'rolled back' nature. Detach the external oblique from the ribs and iliac crest and reflect it laterally. Observe the internal oblique muscle. Study its fibres. Similarly expose the transversus abdominis muscle.

- Obliquus abdominis externus (external oblique of abdomen) (Fig. 14.6).
- Obliquus abdominis internus (internal oblique of abdomen) (Fig. 14.7).
- Transversus abdominis (transverse oblique of abdomen) (Fig. 14.8).

In addition to these anterolateral muscles, the anterior abdominal wall has a vertically running anterior muscle called the rectus abdominis.

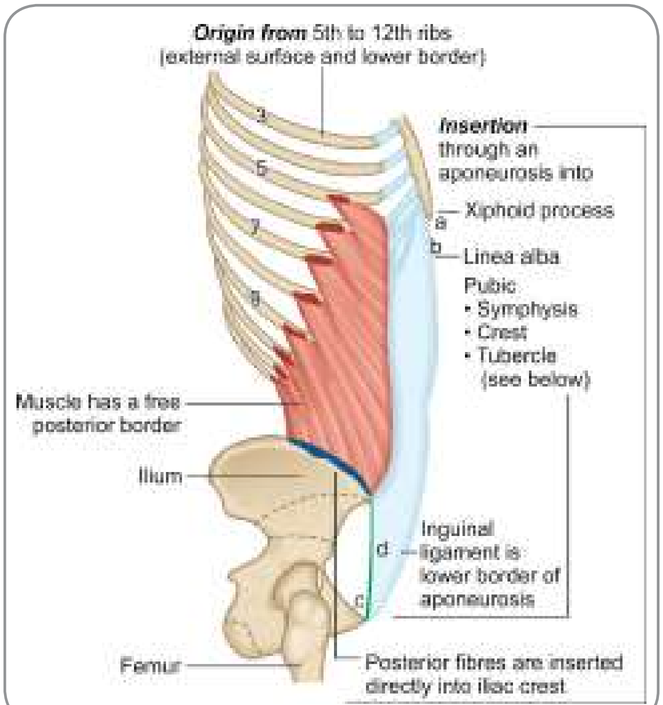


Fig. 14.6: Lateral view of the trunk to show the attachments of the external oblique muscle of the abdomen

Additional Notes on the External Oblique Muscle

The external oblique is the most superficial of the anterolateral muscles of the abdomen. The upper slips of the muscle interdigitate with those of the serratus anterior; the lower slips with those of the latissimus dorsi. The uppermost slip from the 5th rib arises a little behind the junction of the rib with its costal cartilage. Succeeding slips arise further back on the ribs so that the line of origin is, on the whole, oblique passing downwards and backwards to reach the 12th rib.

The lower border of the external oblique aponeurosis is folded on itself and stretches from the anterior superior iliac spine to the pubic tubercle. It is convex towards the thigh and is continuous with fascia lata. The folded and upturned border is called the ***inguinal ligament***. Other modifications related to the aponeurosis of this muscle are the lacunar ligament, pectineal ligament, reflected part of inguinal ligament and the superficial inguinal ring.

Additional Notes on the Internal Oblique Muscle

The fibres arising from the middle one-third of the inguinal ligament are closely related to the inguinal canal. They first pass upwards and medially in front of the lateral part of the canal (forming its anterior wall); then turn backwards and medially above the canal (forming its roof) and finally dip downwards and medially behind it. Here the fibres become tendinous and join those of the transversus abdominis to form the conjoint tendon through which they are attached to the pubic crest and the pecten pubis. The conjoint tendon forms the medial part of the posterior wall of the inguinal canal.

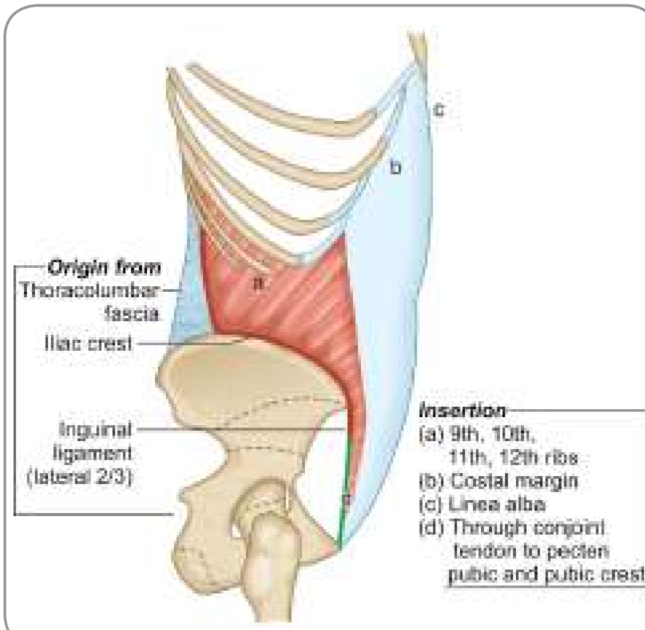


Fig. 14.7: Lateral view of the trunk to show attachments of the internal oblique muscle of the abdomen

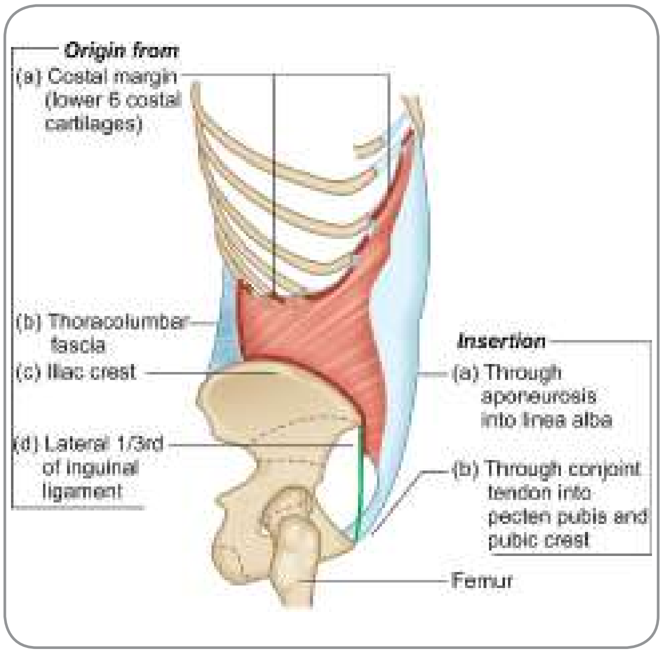


Fig. 14.8: Lateral view of the trunk to show the attachments of the transversus abdominis muscle

Additional Note on the Aponeuroses of the Muscles

The aponeuroses of the all the three anterolateral muscles take part in the formation of the rectus sheath.

Structures Closely Related to Anterolateral Muscles

Linea Alba

Other name: White line

Linea alba is a tendinous raphe present in the midline of the anterior abdominal wall. It is attached above to the xiphoid process and below to the symphysis pubis. It is formed by the interlacing of the fibres of the aponeuroses of the external oblique, the internal oblique and the transversus abdominis muscles of both sides across the midline. It separates the two rectus abdominis muscles from each other.

Inguinal Ligament

Other names: Vesalius ligament, Poupart's ligament, Crural arch, Femoral arch, Fallopian arch.

The inguinal ligament is a thick curved band of fibres that lies at the junction of the abdomen and the front of the thigh. It is attached medially to the pubic tubercle and laterally to the anterior superior iliac spine (Fig. 14.9). It represents the lower border of the aponeurosis of the external oblique muscle, which is folded on itself (upturned end). As a result, the ligament comes to have a grooved upper surface that can be seen if the ligament is viewed from the superior aspect.

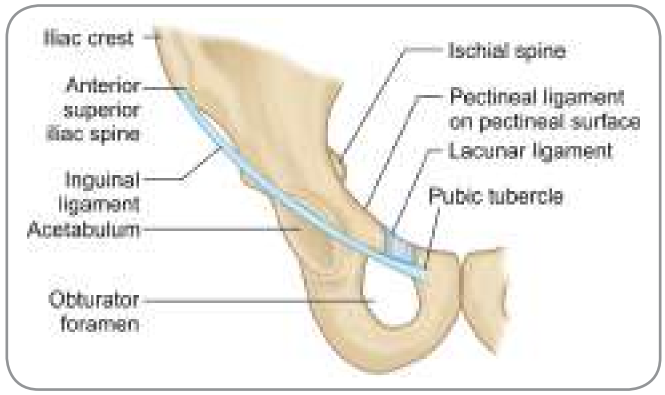


Fig. 14.9: Diagram to show the inguinal ligament and some related structures

Lacunar Ligament

Other name: Gimbernat's ligament.

This is also called the ***pectineal part of the inguinal ligament.*** It is a triangular membrane placed horizontally, behind the medial most part of the inguinal ligament. Its base, directed laterally, is free and forms the medial boundary of the femoral ring.

Pectineal Ligament

Other name: Cooper's ligament,

Some fibres which are continuous with the lacunar ligament extend laterally along the pecten pubis beyond the base of the lacunar ligament. They constitute the pectineal ligament, the fibres of which are firmly adherent to the pecten pubis.

Superficial Inguinal Ring

Other names: Subcutaneous ring, External inguinal ring.

Just above the medial part of the inguinal ligament, an aperture is present in the aponeurosis of the external

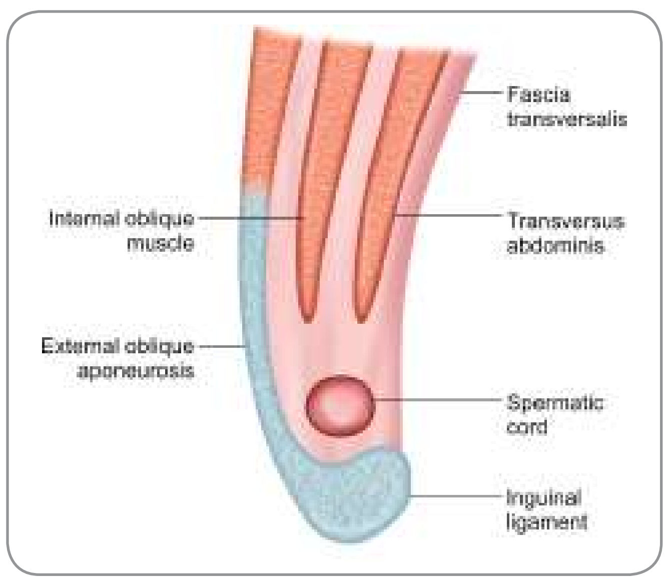


Fig. 14.10: Diagram to show the position of the inguinal canal

oblique muscle called the superficial inguinal ring (Fig. 14.10). It is triangular in shape. The base of the triangle is formed by the pubic crest. The two sides of the triangle form the lateral or lower and the medial or upper margins of the opening which are referred to as crura. The lateral crus is formed by the medial part of the inguinal ligament which is inserted into the pubic tubercle and the medial crus is attached to the front of the symphysis pubis.

At the margins of the ring, the external oblique aponeurosis and overlying fascia continue downwards as a delicate tubular prolongation of fibrous tissue. It covers the spermatic cord and testis and forms their outermost covering called ***external spermatic fascia***.

The superficial inguinal ring is the distal end of the inguinal canal.

Reflected Part of the Inguinal Ligament

The reflected part of inguinal ligament is made up of fibres which pass upwards and medially from the lateral crus of the superficial inguinal ring and disappear under its medial crus (Fig. 14.11). The fibres of the ligaments of the two sides decussate in the linea alba.

Conjoint Tendon

Other names: Tendo conjunctivus, Inguinal aponeurotic fold, Falx aponeurotica.

The conjoint tendon (or falx inguinalis) is made up of the fibres of the aponeuroses of the internal oblique and transversus abdominis muscles which join together and descend to be inserted into the pubic crest and the medial part of the pecten pubis. The conjoint tendon lies behind the superficial inguinal ring. Traced medially, the fibres of the tendon become continuous with the rectus sheath.

The aponeuroses of the internal oblique and transversus muscles fuse lateral to the rectus abdominis in the lower part of the abdominal wall. The more lateral fibres run downwards forming the conjoint tendon, while the more medial ones form the anterior sheath of the rectus abdominis.

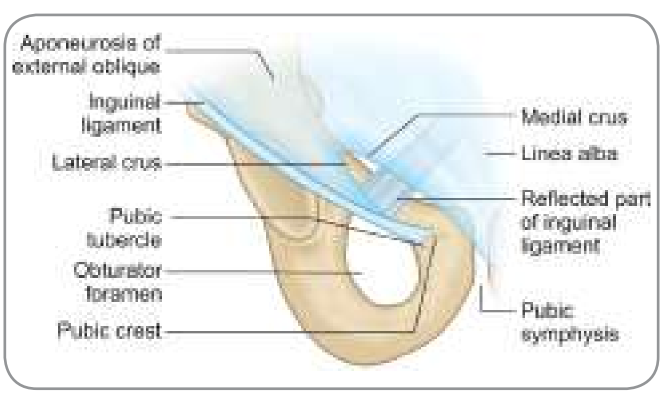


Fig. 14.11: Diagram to show the structure of the superficial inguinal ring

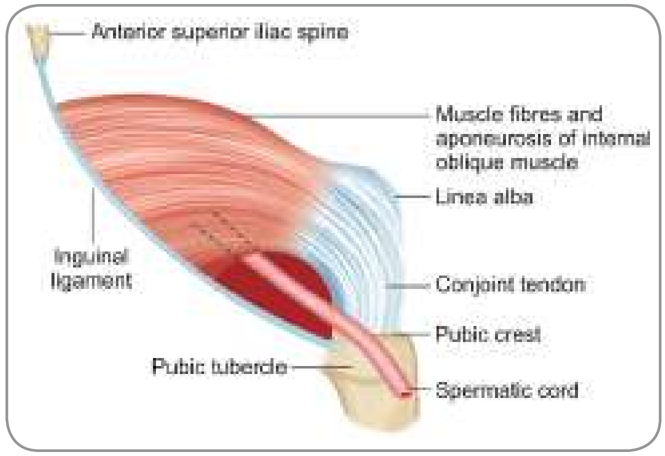


Fig. 14.12: Diagram to show relationship of the internal oblique muscle to the inguinal canal

Inguinal Canal

Other names: Abdominal canal, Velpeau's canal

Inguinal canal is an oblique passage through the anterior abdominal wall placed a little above the medial part of the inguinal ligament (Figs 14.10 and 14.12). It extends between the deep and the superficial inguinal rings. It begins at the deep inguinal ring, situated in the transversalis fascia midway between the anterior superior iliac spine and the pubic symphysis, half an inch above the inguinal ligament. The inguinal canal passes downwards and medially to reach the superficial inguinal ring. It gives passage to the spermatic cord in the male, and the round ligament of the uterus in the female and ilioinguinal nerve in both sexes.

Boundaries of the Inguinal Canal

The canal has an anterior wall, a posterior wall, a roof and floor.

- The ***floor*** is formed by the grooved upper surface of the inguinal ligament, and more medially by the lacunar ligament (Fig. 14.13). The fascia transversalis is adherent to the back of the inguinal ligament and helps to close the canal below.
- The ***roof*** of the canal is formed by the fibres of the internal oblique (Fig. 14.14). The fibres of the transversus abdominis may or may not take part in forming the roof depending on the level to which they descend.
- The ***anterior wall*** of the inguinal canal is formed by:
  - Fleshy fibres of internal oblique over lateral one-third of canal.
  - Aponeurosis of external oblique over entire length of canal.
  - Skin and superficial fascia.
- The ***posterior wall*** of the canal is formed by:
  - The fascia transversalis over the entire extent of canal. It is separated from the peritoneum by extraperitoneal fat.

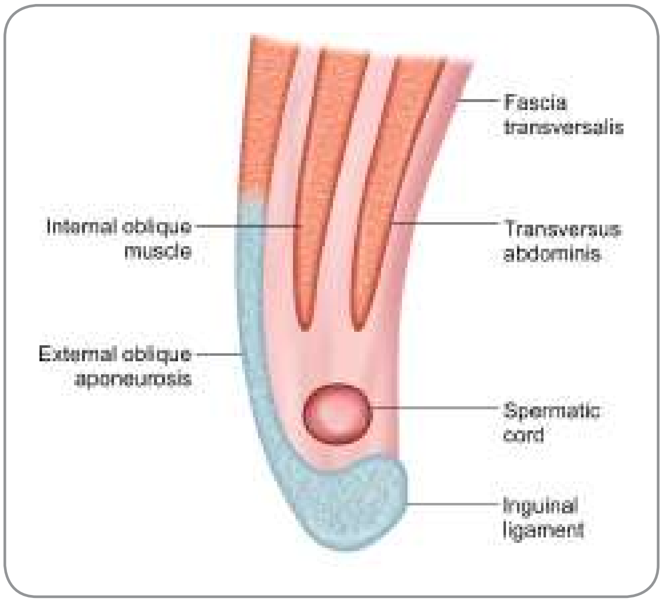


Fig. 14.13: Sagittal section through inguinal canal

- Conjoint tendon over the medial half of canal.
- Reflected part of inguinal ligament over the medial one-third of canal.

The presence of inguinal canal would appear to weaken the lower part of the anterior abdominal wall but this is compensated by various inbuilt mechanisms and modifications. They are as follows:

- The oblique shape of the inguinal canal itself offers protection. Any increase in intra-abdominal pressure will cause the posterior wall to approximate to the anterior wall like a flap valve.
- Though the deep inguinal ring present in the transversalis fascia is a potential weak point in the posterior wall, it is compensated by the strong anterior wall in that area by the fleshy fibres of internal oblique.
- Similarly, the presence of the superficial ring in the anterior wall medially is compensated by the strong posterior wall made of conjoint tendon and reflected part of inguinal ligament.
- The arched fibres of internal oblique and to some extent transverses abdominis forming the roof also adds to the defense mechanism. In normal standing position, they are constantly active and in increased intra-abdominal pressure, the contraction of the internal oblique is accentuated and causes the roof to approximate to the floor.
- In increased intra-abdominal pressure, in males, the testis is pulled by the cremaster muscle towards the superficial inguinal ring thereby occluding the pathway. This also adds to the protection.

In spite of all these defense mechanisms, the inguinal canal is a potential site for hernia and inguinal hernia is one of the most common herniae in males.

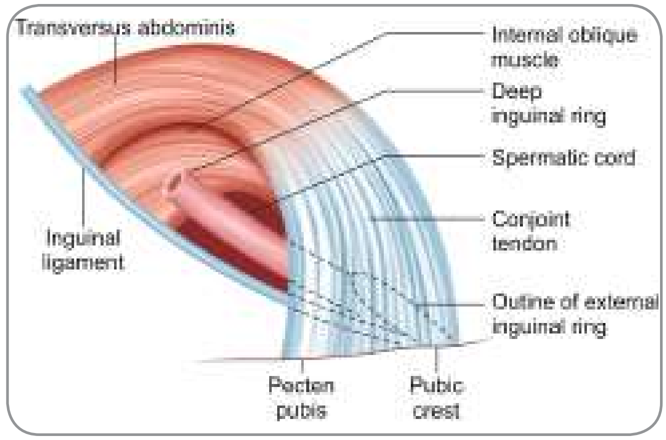


Fig. 14.14: Inguinal canal seen from behind

Dissection

As you study the muscles of the anterior abdominal wall, focus your attention on the lower part of the wall and try to look for the inguinal canal. Identify the superficial and deep inguinal rings. Locate the conjoint tendon. Review the factors which provide a natural closure mechanism for the inguinal canal.

Contents of Inguinal Canal

Spermatic cord in the males and the round ligament of the uterus in the females is present through out the extent of the inguinal canal. In both sexes, ilioinguinal nerve pierces the internal oblique to enter the inguinal canal about midway and leaves at the superficial inguinal ring.

Spermatic Cord and its Coverings

The inguinal canal gives passage to the spermatic cord in the male. The structures which constitute the spermatic cord are as follows:

- The ***ductus deferens*** is a thick walled tube that carries spermatozoa formed in the testis to the male excretory passages.
- Arteries present in the spermatic cord are:
  - The testicular artery to the testis (a branch of abdominal aorta).
  - An artery to the ductus deferens (a branch of inferior vesical artery).
  - Another artery to the cremaster muscle descends along the cord (a branch of inferior epigastric artery).
- The veins draining the testis and epididymis form a plexus around the ductus deferens called the ***pampiniform plexus***. Near the superficial inguinal ring, the plexus ends in three or four longitudinal veins that pass through the inguinal canal.
- The genital branch of the genitofemoral nerve enters the spermatic cord at the deep inguinal ring. It supplies the cremaster muscle and gives some branches to the skin of the scrotum.

- A plexus of sympathetic nerves runs along the testicular artery.
- The lymphatic vessels from the testis also pass through the spermatic cord.

Coverings of the Cord

In early embryonic life the testes lie within the abdomen, but in later months of pregnancy they descend through the inguinal canal into the scrotum. As each testis passes through the abdominal wall it carries extensions from its layers.

These extensions which form the coverings of the testis, and of the cord, are as follows (within outwards) (Fig. 14.15).

- The ***internal spermatic fascia*** is a prolongation of transversalis fascia from the margins of the deep inguinal ring.
- The ***cremasteric fascia*** is an extension from the internal oblique muscle. The fascia contains several muscle bundles that constitute the cremaster muscle.
- The ***external spermatic fascia*** is an extension from the margins of the superficial ring (i.e., from the aponeurosis of the external oblique). It surrounds the cord below the level of the superficial inguinal ring.

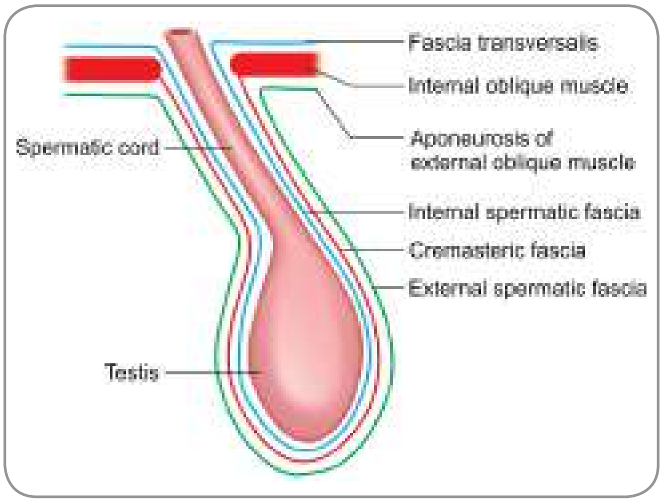


Fig. 14.15: Schematic diagram to show coverings of the spermatic cord and of the testis

Rectus Abdominis

The attachments of this muscle are given in Table 14.2 and are shown in Figure 14.16.

Pyramidalis

The pyramidalis is a small muscle placed in front of the rectus abdominis, within its sheath (Fig. 14.16). It is triangular in shape. Its base (or origin) is attached to the front of the pubis and the symphysis pubis. Its apex is inserted into the linea alba. It is supplied by the subcostal nerve.

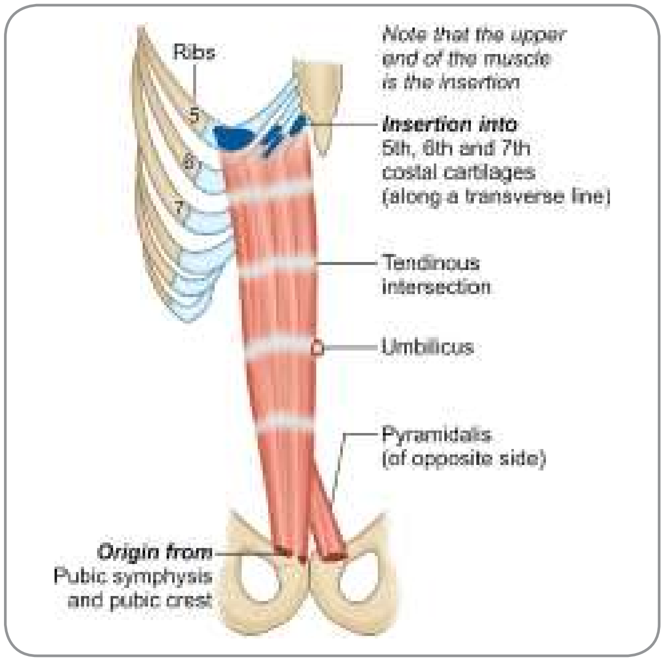


Fig. 14.16: Scheme to show the attachments of the rectus abdominis

Table 14.2: Rectus abdominis	
Origin	The muscle has two tendons of origin: 1. The medial tendon is attached to the front of the symphysis pubis. 2. The lateral tendon is attached to the pubic crest.
Insertion	5th, 6th, and 7th costal cartilages along horizontal line.
Nerve supply	Lower 6 or 7 thoracic nerves.
Action	• Bends the trunk forwards. • Supports abdominal viscera. • Increases intra-abdominal pressure.
Notes	• The lower end is the origin, the upper end the insertion. • The origin is narrow, the insertion is broad. • The muscles of the two sides are separated by the linea alba. • The medial tendon of origin is superficial, the lateral deep. • A number of tendinous intersections (usually three) run transversely across the muscle.

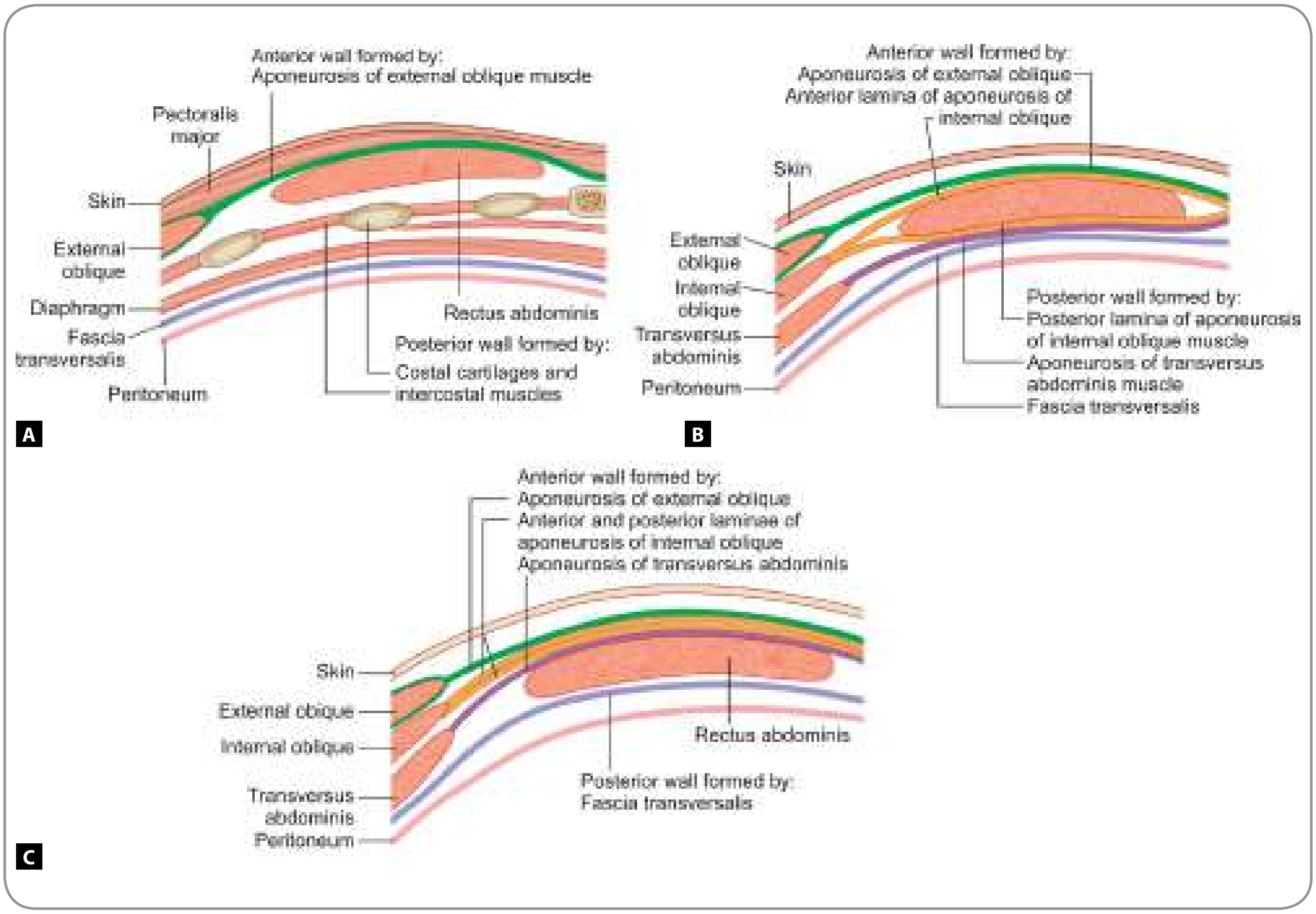


Fig. 14.17A to C: Schematic transverse sections through the rectus abdominis muscle and its sheath at upper, middle and lower layers

Rectus Sheath

The rectus abdominis is enclosed in a fibrous sheath formed by the aponeuroses of the oblique and transverse muscles. This is the ***rectus sheath***. The anterior wall of the rectus sheath extends the entire length of the muscle whereas the posterior wall is deficient at some levels. Tendinous intersections extend between the overlying rectus sheath and the anterior aspect of the rectus abdominis; these intersections are usually present in three places—one at the level of xiphoid process, one at the level of umbilicus and one between them.

Formation of Rectus Sheath

The formation of the rectus sheath differs in different regions. For convenience, the formation of rectus sheath is discussed at three levels.

1. Above the level of costal margin;
2. Between the costal margin and midway between the umbilicus and pubic symphysis and
3. Below the level mentioned above.

The manner in which the sheath is formed is shown in Figures 14.17A to C. For a thorough understanding of the sheath and its formation, it is preferable to study the midlevel (between the costal margin and midway between the umbilicus and pubic symphysis) first and then the other levels.

- ***Between the costal margin and midway between the umbilicus and pubic symphysis:*** The typical arrangement of rectus sheath is seen between the level of the costal margin to that of midway between the umbilicus and the pubic symphysis (Fig. 14.17B). On reaching the lateral margin of the rectus abdominis, the aponeurosis of the internal oblique muscle splits into anterior and posterior laminae. In this region, the anterior and posterior laminae of internal oblique passes anterior and posterior to the rectus abdominis muscle. The anterior lamina of the aponeurosis of the internal oblique joins with the external oblique aponeurosis superficial to it to form the anterior wall of the sheath. The posterior lamina of the aponeurosis of the internal oblique joins with the aponeurosis of the transversus abdominis deep to it to form the posterior wall of the rectus sheath.

- ***Below the level, midway between the umbilicus and pubic symphysis:*** Both the anterior and posterior laminae of the internal oblique pass superficial to the rectus abdominis muscle. The aponeurosis of the transversus abdominis also passes anterior to the rectus abdominis muscle at this level. Hence, the lower part of the rectus abdominis rests directly on transversalis fascia and the posterior part of the sheath is deficient. The aponeurosis of the transversus abdominis, and both laminae of the internal oblique join the external oblique aponeurosis in forming the anterior wall of the sheath. The lower free border of the posterior part of the sheath is called the ***arcuate line*** (Fig. 14.18) which lies on the transversalis fascia.
- ***Above the level of costal margin:*** When traced upwards, the aponeurosis of the transversus abdominis and the posterior lamina of the internal oblique end by gaining attachment to the costal margin. Hence, above the level of costal margin also, the posterior wall of the rectus sheath is deficient. Hence, at this level, the rectus abdominis lies directly on the costal cartilages and intercostal muscles that separate it from the diaphragm.

Contents of Rectus Sheath

- ***Rectus abdominis*** and ***pyramidalis muscles***
- The ***superior epigastric artery***—which enters the sheath at its upper end by piercing the posterior wall.
- The ***inferior epigastric artery***—which runs upwards over the transversalis fascia and enters the sheath by passing anterior to the arcuate line.
- The superior epigastric vein, a tributary of internal thoracic vein and the inferior epigastric vein, a tributary of the external iliac vein.
- The ***lower intercostal nerves***—which run forwards between the internal oblique and the transversus abdominis muscles. They enter the sheath by piercing the posterior lamina of the internal oblique in its lateral part (Fig. 14.19).

The contents are shown in Figure 14.18, in which the posterior wall of the sheath has been shown after the muscle has been removed.

Added Information

Additional Notes on the Formation of Rectus Sheath

As more and more anatomical studies are taken up, a newer concept regarding the formation of the rectus sheath has evolved.

The aponeuroses of all the three abdominal muscles are split into two laminae. The anterior laminae of all the three muscles run in an obliquely upward direction, whereas the posterior laminae of the three abdominal muscles run in an obliquely downward direction.

The anterior wall of the rectus sheath is formed by both the anterior and posterior laminae of external oblique aponeurosis and the anterior lamina of internal oblique. The posterior wall of the sheath is formed by the posterior lamina of the internal oblique and both the anterior and posterior laminae of the aponeurosis of transversus abdominis. Therefore, each of the anterior and posterior layers of the rectus sheath is formed by three laminae. The middle lamina in both the layers runs at right angles to the others. Fibres of each lamina decussate with the fibres of the opposite side and also decussate anteroposteriorly between the laminae of the same side. The line of decussation in the midline is called the linea alba. In this arrangement, all the three abdominal muscles can be considered to be digastric muscles with the intermediate tendon formed by the linea alba.

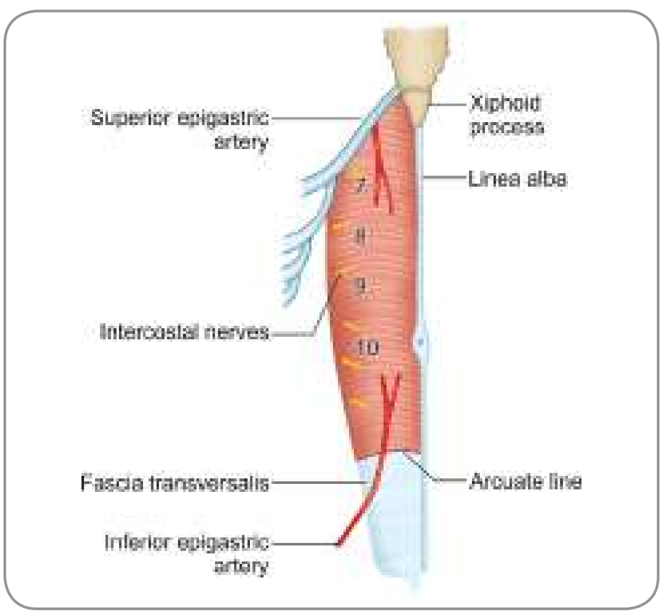


Fig. 14.18: Diagram showing contents of the rectus sheath

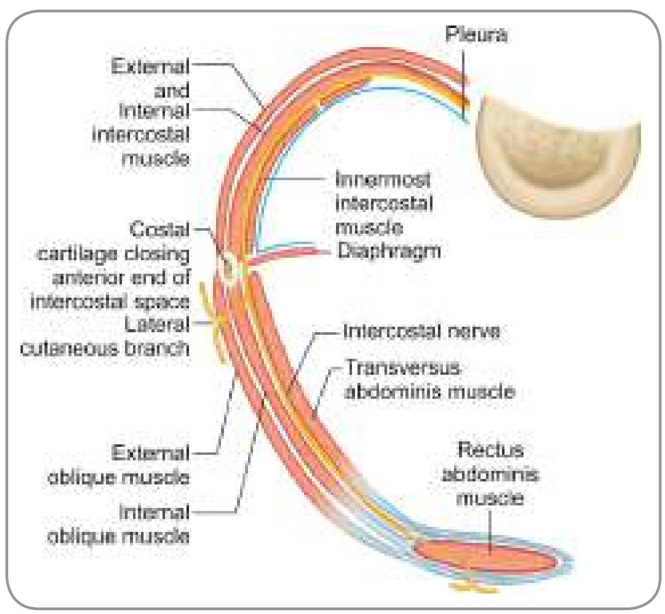


Fig. 14.19: Scheme to show the course of one of the lower intercostal nerves

Dissection

Once you have identified the rectus sheath, open the same by an incision shaped like a T. See the various tendinous intersections and contents. Do a detailed study. Transect the muscle and view the posterior aspect of the sheath.

Nerve Supply of Muscles of Anterior Abdominal Wall

The muscles of the anterior abdominal wall are supplied by:
- Branches from the lower six intercostal nerves (T6 to T11)
- The subcostal nerve (T12) and
- The iliohypogastric and ilioinguinal nerves (both L1).

The intercostal nerves and the subcostal nerve give branches to the external and internal oblique muscles, the transversus abdominis and the rectus abdominis.

The iliohypogastric nerve gives branches only to the internal oblique and transversus muscles.

The ilioinguinal nerve gives branches only to the internal oblique.

The subcostal nerve also supplies the pyramidalis (Fig. 14.20).

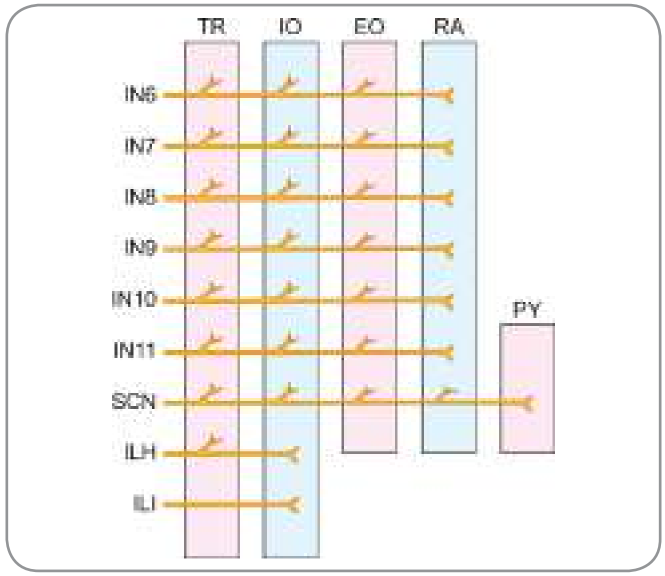


Fig. 14.20: Scheme to show innervation of muscles of the anterior abdominal wall. **Key: IN6 to IN11.** 6th to 11th intercostal nerves **SCN.** Subcostal nerve **ILH.** Iliohypogastric nerve **ILI.** Ilioinguinal nerve **TR.** Transversus abdominis **IO.** Internal oblique **EO.** External oblique **RA.** Rectus abdominis **PY.** Pyramidalis

Nerves of Anterior Abdominal Wall

The various nerves to be seen in relation to each half of the anterior abdominal wall are (Fig. 14.20):
- Anterior parts of the lower five pairs of intercostal nerves
- The subcostal nerve
- The iliohypogastric nerve
- The ilioinguinal nerve (Fig. 14.21)
- The genitofemoral nerve (Fig. 14.22).

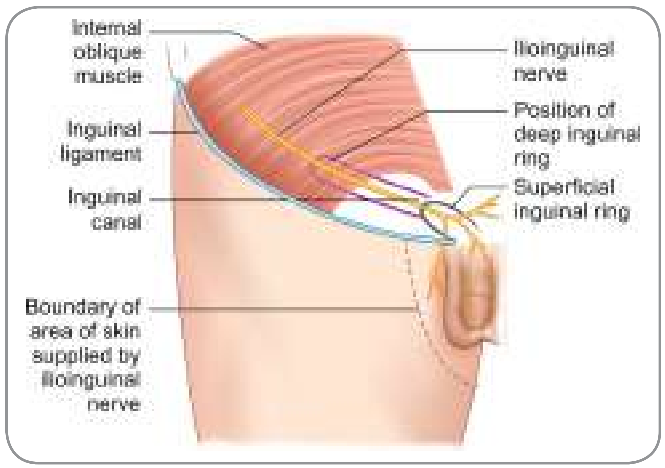


Fig. 14.21: Scheme to show the course of the anterior part of the ilioinguinal nerve

Development

Development of anterior wall muscles: As already noted, the somites form the myotomes. Each myotome is subdivided into a dorsal epimere and a ventrolateral hypomere.The epimeres give rise to the posterior muscles which are supplied by the dorsal primary rami of the spinal nerves. The hypomeres extend into the somatopleuric mesoderm of the anterolateral body wall. In the abdominal region, due to the absence of ribs and costal cartilages, all the hypomeric segments fuse and form one continuous sheet of muscle. This continuous sheet divides into a narrow ventral portion and a broad lateral portion. The ventral portion becomes the rectus abdominis and the lateral portion the three cardinal muscles.

Cutaneous Innervation of Anterior Abdominal Wall

The cutaneous innervation of the anterior abdominal wall is through the lower five intercostal nerves, the subcostal nerve and the iliohypogastric nerves. Each intercostal nerve gives off a lateral cutaneous branch that divides further into anterior and posterior branches which supply the skin over the abdomen. Anteriorly, the intercostal nerve terminates by becoming superficial as the anterior cutaneous branch. The lowest two lateral cutaneous branches (from T10 and T11) become superficial by piercing the external oblique muscle.

Apart from the lower five intercostal nerves (T7, T8, T9, T10, T11), anterior cutaneous and lateral cutaneous branches also arise from the subcostal nerve (T12), and from the iliohypogastric nerve (L1). They descend to the gluteal region to supply the skin over the anterior gluteal region (Fig. 14.22 and 14.23).

The seventh and eighth nerves supply the skin over the epigastrium, ninth nerve supplies the skin above the umbilicus, tenth supplies the skin over the umbilicus and eleventh supplies the skin below the umbilicus.

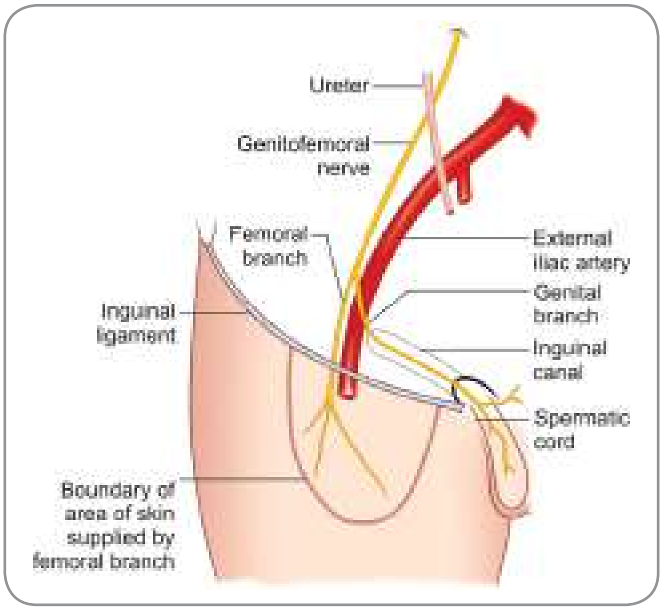


Fig. 14.22: Scheme to show the course of the genitofemoral nerve

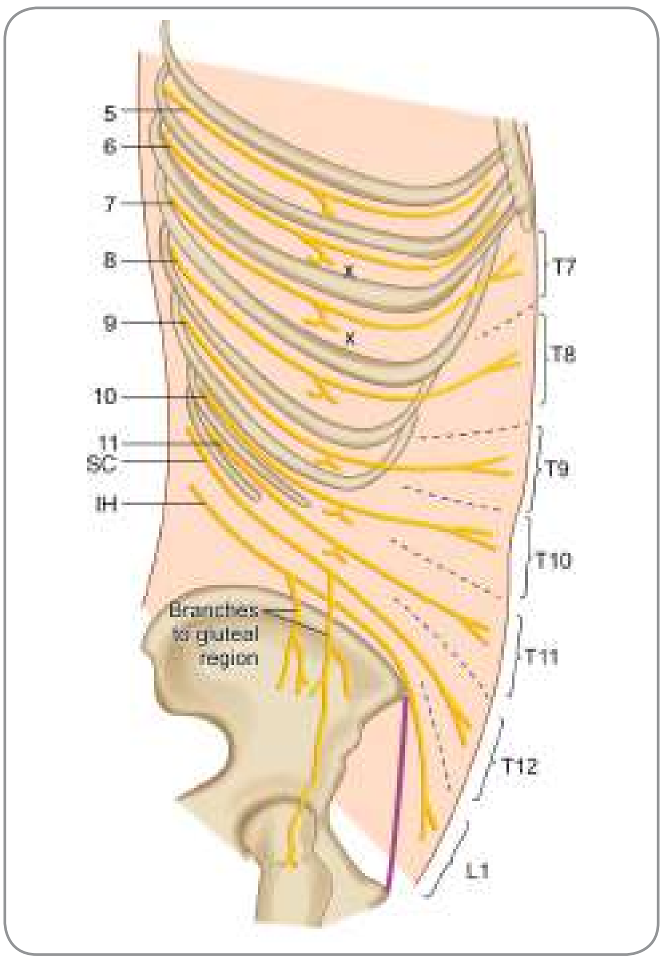


Fig. 14.23: Course of intercostal nerve as seen from the lateral side **SC.** Subcostal nerve **IH.** Iliohypogastric nerve

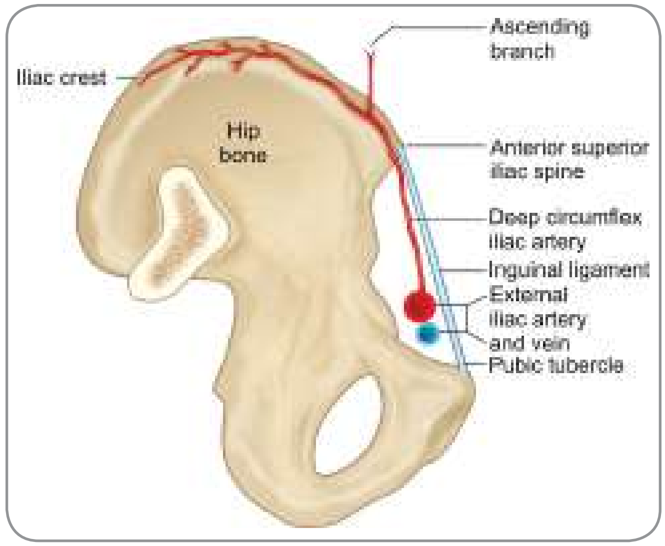


Fig. 14.24: Scheme to show course of the deep circumflex iliac artery

Blood Vessels of Anterior Abdominal Wall

The various arteries that supply the abdominal wall are as follows:

- Lower two (10th and 11th) posterior intercostal arteries—direct branches of descending thoracic aorta.
- Subcostal artery—also a branch of descending thoracic aorta.
- Musculophrenic and superior epigastric arteries—terminal branches of the internal thoracic artery.
- Inferior epigastric and deep circumflex iliac branches of external iliac artery (Fig. 14.24).
- Three superficial branches arising from the upper part of the femoral artery namely superficial epigastric, superficial circumflex iliac and superficial external pudendal arteries.
- Terminal parts of lumbar arteries which lie in the posterior abdominal wall also supply the anterolateral abdominal wall.

Apart from the deep circumflex iliac artery, all other arteries give cutaneous branches to supply the skin over the anterior abdominal wall.

Inferior Epigastric Artery

The inferior epigastric artery arises from the external iliac artery just above the inguinal ligament (Fig. 14.25). Its initial part is intimately related to the deep inguinal ring. It first runs medially, inferior to the ring and then runs upwards medial to the ring. The artery continues upwards and medially on the posterior aspect of the anterior abdominal wall and enters the rectus sheath by passing in front of the arcuate line (Fig. 14.18). Within the sheath, it anastomoses with the superior epigastric artery.

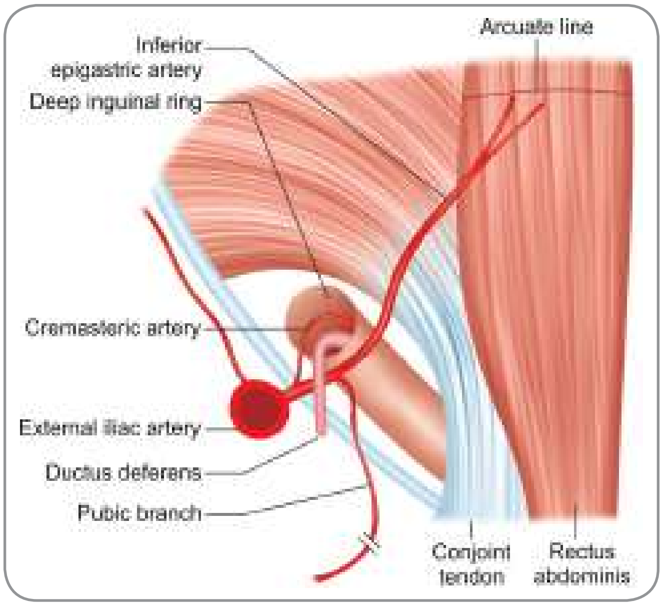


Fig. 14.25: Scheme to show the course of the inferior epigastric artery. The inguinal region and the lower part of the anterior abdominal wall are viewed from behind

Apart from its relationship to the deep inguinal ring mentioned above, the artery is related to the ductus deferens (in the male) or to the round ligament of the uterus (in the female). These wind round its lateral side to enter the deep inguinal ring (Fig. 14.25). The artery raises a fold of peritoneum called the ***lateral umbilical ligament*** on the back of the anterior abdominal wall.

Branches

The inferior epigastric artery gives off the following branches:

- The ***cremasteric*** branch enters the deep inguinal ring along with the spermatic cord. It supplies the cremaster muscle.
- The ***pubic*** branch passes medially and downwards in close relation to the femoral ring. It anastomoses with the pubic branch of the obturator artery. Occasionally, this branch is large and the obturator artery then appears to be its continuation.
- Branches are given off to muscles of the anterior abdominal wall and to the skin overlying them.

Deep Circumflex Iliac Artery

The deep circumflex iliac artery arises from the lateral side of the external iliac artery. It runs laterally behind the inguinal ligament to reach the anterior superior iliac spine. It then passes along the inner lip of the iliac crest, deep to the transversus abdominis muscle. At about the middle of the iliac crest, it pierces the muscle and continues to run backwards between it and the internal oblique. It gives branches to the muscles of the anterior abdominal wall.

Superficial Branches of Femoral Artery which Supply the Abdominal Wall

These branches arise from the femoral artery just below the inguinal ligament. They become superficial by piercing the femoral sheath and the cribriform fascia. They contribute to the supply of the lower part of the abdominal wall.

- The ***superficial circumflex iliac artery*** runs laterally towards the anterior superior iliac spine.
- The ***superficial epigastric artery*** ascends across the inguinal ligament and runs towards the umbilicus.
- The ***superficial external pudendal artery*** runs medially to supply skin over the external genitalia and over the lower part of the abdomen.

Branches from the various arteries described above supply muscles in the abdominal wall.

Veins of Anterior Abdominal Wall

The veins of the anterior abdominal wall correspond to the arteries described above. The veins that accompany the superficial branches of the femoral artery drain into the long saphenous vein.

Lymphatic Drainage of Anterior Abdominal Wall

Lymphatic Drainage of Skin

- The skin above the level of the umbilicus anteriorly and above the iliac crest at the back drains into the axillary lymph nodes (Figs 14.26 and 14.27).
- The skin of the anterior abdominal wall below the umbilicus drains into the superficial inguinal lymph nodes.

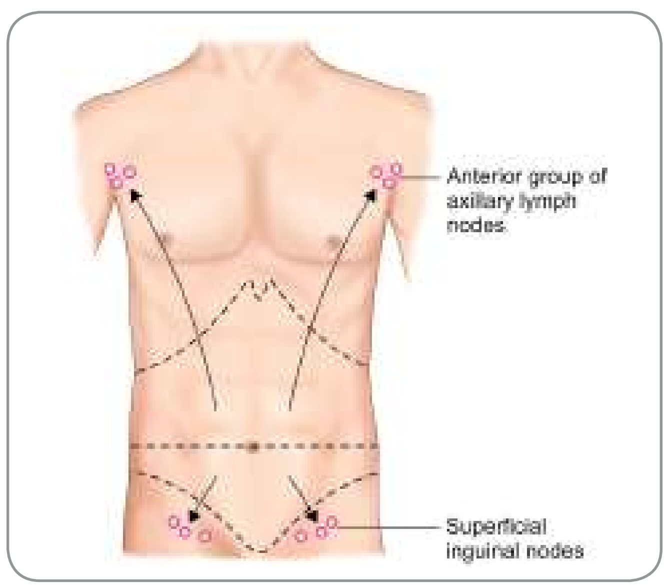


Fig. 14.26: Lymphatic drainage of anterior aspect of trunk

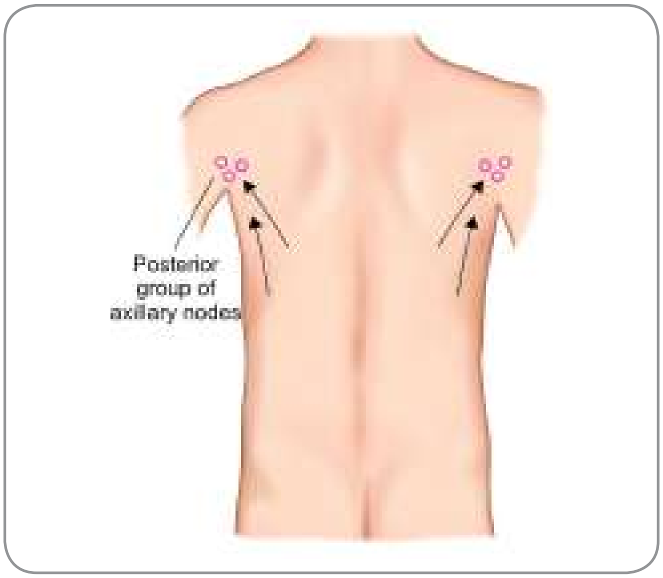


Fig. 14.27: Posterior aspect of trunk to show its lymphatic drainage

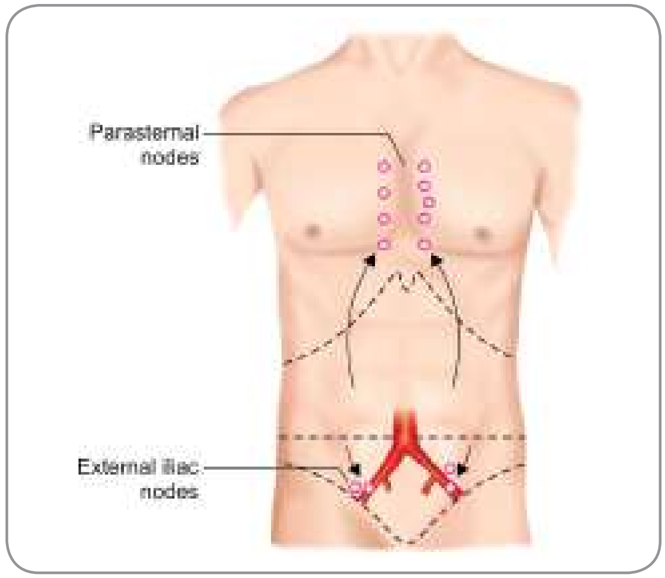


Fig. 14.28: Lymphatic drainage of deeper tissues of anterior abdominal wall

Lymphatic Drainage of Deeper Tissues

- The vessels from the upper part of the abdominal wall travel along the superior epigastric vessels to reach parasternal lymph nodes.
- The vessels from the lower part of the anterolateral abdominal wall travel along the inferior epigastric and circumflex iliac vessels. Passing through nodes placed along these vessels they reach the external iliac nodes (Fig. 14.28) lying along the external iliac artery.

Clinical Correlation

Lymphatic Drainage

The lymphatic drainage of the abdominal wall described above is important. Infections or malignancy in relation to the abdominal wall can drain into widely separated lymph nodes.

Superficial Veins

- The superficial veins over the anterior abdominal wall are normally inconspicuous. In some conditions they become prominent.
- The umbilicus is one of the sites at which tributaries of the portal vein communicate with systemic veins. In case of obstruction to the portal vein, these communications become very prominent and are seen as veins that radiate from the umbilicus which is called the ***caput medusa*** because of its appearance.
- Superficial veins running more or less vertically over the lateral part of the anterior abdominal wall connect tributaries of the lateral thoracic vein with tributaries of the superficial epigastric vein. The main channel of communication is called the ***thoracoepigastric vein***. The lateral thoracic vein further drains into the axillary vein and the superficial epigastric vein joins the great saphenous vein which in turn, joins the femoral vein. Hence, the thoracoepigastric vein serves as a collateral channel of communication between the upper limbs (axillary vein) and lower limbs (femoral vein). In case of obstruction to either the superior or inferior vena cava these superficial veins enlarge considerably and serve as alternative channels through which blood can flow one vena cava to the other and thus reach the heart. The direction of blood flow in superficial veins gives a clue to the identity of the blocked vena cava.

Umbilicus

Early in foetal life the region of the future umbilicus is marked by a large gap in the future abdominal wall. Several structures pass through the gap as follows:

- The ***vitellointestinal duct*** connects the embryonic gut to the yolk sac. In the normal course of development, this duct disappears.
  - If the duct remains patent, a channel is present through which intestinal contents flow out at the umbilicus. This condition is called as the ***faecal fistula***.
  - Sometimes, the vitellointestinal duct may not communicate with the exterior but part of it may remain patent as a diverticulum communicating with the gut which is called ***Meckel's diverticulum***.
  - Remnants of the vitellointestinal duct may also give rise to tumours at the umbilicus.
- The ***allantoic diverticulum*** is a tube like structure that is connected, at one end, to the distal part of the embryonic gut (cloaca). In later development, the cloaca is partitioned into a part that forms the rectum and another part that forms the urinary bladder, and after this partition is established the allantoic diverticulum comes to communicate with the urinary bladder. The other end of the allantoic diverticulum is blind which passes through the umbilical opening. Normally, the allantoic diverticulum is occluded and forms a fibrous band called the ***urachus***. This band connects the apex of the urinary bladder to the umbilicus. Occasionally, however the urachus remains patent resulting in a communication between the urinary bladder and the umbilicus (***urinary fistula***).

contd...

Clinical Correlation *contd…*

- In the early embryo, the abdominal cavity is small. Meanwhile the gut undergoes rapid growth and the abdomen is unable to accommodate it. As a result, some coils of intestine pass out of the abdomen through the umbilical opening referred to as ***physiological hernia***. Later, as the abdomen becomes larger in size, the coils return into the abdominal cavity. In some cases, the coils of gut fail to return, and the infant is born with coils of gut protruding out of the abdomen in the region of the umbilicus. This condition is referred to as ***congenital umbilical hernia*** or ***exomphalos***.
- The original umbilical opening is obliterated by growth of tissue into it from all sides. However, in some cases, growth of the wall below the future umbilicus is deficient resulting in a gap in the abdominal wall. Simultaneously, the anterior wall of the urinary bladder is also absent. This condition is called ***ectopia vesicae*** in which, the posterior wall of the urinary bladder is exposed to the exterior and can be seen on the surface of the body.

Surgical incisions in anterior abdominal wall: The abdomen is a region that is frequently operated upon. To reach any of the viscera, the abdominal wall has to be incised (cut across) to enter the peritoneal cavity. This is called ***laparotomy***. Incisions in the abdominal wall are not made at random, but are based on certain principles. The primary objective of an incision is to provide good exposure of the region to the operated upon. At the same time, due importance has to be given to the integrity of the abdominal wall and incisions should be planned in such a way that after healing the abdominal wall returns to as near a condition as it was before the operation.

- Some of the factors that influence the placing of incisions are the direction of muscle fibres, and the position of nerves.
- Some commonly used incisions are as follows:
  - ***Midline incisions***—made through the linea alba. The advantage of this incision is that no muscles are cut across. However, the main disadvantage is the poor healing because of poor vascularity. The linea alba is broader in the upper part because the rectus abdomini are closer together in the lower part than they are at higher levels. Hence, median incisions are easier above the umbilicus. However, the resulting scar may sometimes be weak and an ***epigastric hernia*** may occur, whereas midline incisions below the umbilicus are less likely to lead to hernia as this region is protected by the recti which are close to each other.
  - ***Paramedian incisions*** are made about one inch lateral to the midline.
    - They may be supraumbilical or infraumbilical.
    - The anterior wall of the rectus sheath is incised and the rectus muscle retracted laterally. As the nerves to the rectus abdominis enter it from the lateral side it is safe to retract the muscle laterally. The posterior wall of the sheath, the underlying fascia and the peritoneum are then incised to gain access to the peritoneal cavity.
  - ***Pararectal incisions are explained as follows:*** A vertical cut is made along the lateral margin of the rectus abdominis, and the muscle is retracted medially. As this is done, the nerves passing into the muscle from the lateral side come into view and have to be carefully preserved by retracting them up and down. The posterior wall of the sheath is now incised. The incision is not favoured as access provided is small, and the incision cannot be enlarged without cutting one or more nerves.
  - ***Vertical incision through the rectus abdominis (transrectal incision):*** In this incision, the rectus abdominis muscle and its sheath are cut vertically. Such an incision is not to be favoured as nerve supply to part of the rectus abdominis medial to the incision is destroyed and this part of the muscle degenerates.
  - ***Transverse incisions*** may be made through the abdominal wall, and the incision can include the rectus abdominis. Injury to nerves can be prevented by placing the cut parallel to the course of the nerves. In any case, injury to more than one nerve is unlikely.
    From the point of view of retaining integrity of the abdominal wall, the best incisions are those that split each layer of muscle along the length of its fibres. As the fibres of different layers run in different directions the area of exposure is small. The best known muscle splitting incision is the ***grid-iron*** (or ***McBurney's***) incision used for operations on the appendix.
  - A line is drawn joining the umbilicus to the right anterior superior iliac spine. A point on this line at the junction of the medial two-thirds and lateral one-third is called ***McBurney's point***. The grid iron incision is made through this point at right angles to the line drawn. The length of the line depends on the degree of exposure desired. As each layer of muscle is exposed its fibres are split along the line of the fibres and retracted till the fascia transversalis and peritoneum are exposed.
    In addition to the incisions described above various others are used for special purposes. An abdominothoracic incision is used when it is necessary to enter both the abdominal and thoracic cavities.

Herniae through Abdominal Wall

The term hernia is applied to a condition in which the contents of a cavity protrude out of it through a weak area in its wall. Most herniae are seen in relation to the abdomen. The process of development of hernia in the abdominal wall is as follows:

Abdominal viscera exert pressure on the abdominal wall, and this pressure is increased considerably during acts like coughing or defecation. If there is a gap (or weakened area) in the abdominal wall, repeated pressure against it can cause a process of peritoneum to pass out through the gap into subcutaneous tissues. Further pressure gradually increases the size of the peritoneal process that gradually becomes sac like. As the sac enlarges, coils of intestine (or other abdominal contents) may enter it. Such a ***hernial sac*** can become very large, but the site of the original protrusion remains narrow and is referred to as the ***neck of the hernial sac***. Skin and other tissues that cover the sac are called ***coverings of the hernia***. Abdominal contents that enter the sac are the ***contents of the hernia***.

Usually pressure over a hernia can push its contents back into the abdominal cavity. Such a hernia is said to be ***reducible***.

Sometimes sudden increase in intra-abdominal pressure may push contents into the hernia, which sometimes may not be reducible back to the abdominal cavity. Pressure exerted by the margins of the narrow neck of the hernia can cut off vascular supply of the contents. The condition is then called ***strangulated hernia*** (which is an emergency requiring urgent surgery).

contd…

Clinical Correlation *contd…*

Inguinal Hernia

In the abdominal wall, inguinal canal is one of the potential sites for herniation of abdominal contents. Though there are a number of protective factors present to prevent herniation as already mentioned, inguinal hernia are still one of the most common of all hernia in human because of the following reason.

- In foetal life, the inguinal canal serves as a passage through which the testis passes through the abdominal wall to descend into the scrotum. A tubular process of peritoneum called the ***processus vaginalis*** passes through the canal and facilitates the descent of the testis. Normally, the greater part of the processus vaginalis is obliterated, but the part around the testis becomes the tunica vaginalis. Sometimes, the processus vaginalis (or parts of it) may persist as a patent channel into which herniation of abdominal contents may occur. In such a hernia, the contents pass through the deep inguinal ring, the inguinal canal, and the superficial ring and can even extend into the scrotum. This type of hernia is called an ***indirect inguinal hernia***. In some cases, the processus vaginalis gets obliterated, but weakness remains in the region of the inguinal canal leading to formation of hernia.
- Another reason for occurrence of inguinal hernia can be weakening of muscles with age. This results in a ***direct inguinal hernia*** described below.

Indirect Inguinal Hernia

This type of hernia is seen in young individuals. It is seen more commonly on the right side probably because the right testis descends into the scrotum later than the left testis. Indirect inguinal herniae are much more common in the male than in the female. This is because the inguinal canal is much narrower in the female as the ovary does not pass through it. The herniae are frequently bilateral. The neck of the sac of an indirect inguinal hernia lies at the deep inguinal ring, and is ***lateral*** to the inferior epigastric vessels.

- The coverings of an indirect inguinal hernia are the same as the coverings of the testis. From deep to superficial these are:
  - Extraperitoneal tissue,
  - Internal spermatic fascia,
  - Cremasteric fascia,
  - External spermatic fascia and
  - Skin.
- An indirect inguinal hernia may be of various types as follows:
  - When the processus vaginalis remains fully patent the contents of the hernia reach right up to the scrotum. This is called the ***congenital vaginal hernia*** or ***complete hernia***.
  - In some cases, the processus vaginalis remains patent but has no communication with the tunica vaginalis. Hernial contents do not enter the scrotum, but are present in relation to the spermatic cord. This is a ***congenital funicular hernia***.
  - The processus vaginalis may persist only in the region of the inguinal canal (i.e., it does not persist beyond the superficial inguinal ring). In such cases the hernial swelling is small (***bubonocele***).

Direct Inguinal Hernia

In this type of hernia, the sac does not pass through the deep inguinal ring, but enters the inguinal canal by pushing through the posterior wall of the canal. Because of this, the neck of the sac lies ***medial*** to the inferior epigastric vessels in contrast to the sac of an indirect hernia which will always be ***lateral*** to the artery.

- The region of the anterior abdominal wall through which a direct inguinal hernia takes place is triangular. It is bounded:
  - Laterally by the inferior epigastric artery,
  - Medially by the lateral border of the rectus abdominis and
  - Inferiorly by the inguinal ligament.
- This is called the ***Hesselbach's triangle***.
- The triangle is divided into medial and lateral parts by the obliterated umbilical artery and the direct inguinal hernia can occur in either of the parts. According to their position they are named ***lateral direct inguinal hernia*** and ***medial direct inguinal hernia***.
- Sometimes, a small inguinal hernia may be confused with a femoral hernia. The two can be distinguished by the fact that a femoral hernia occurs in the femoral canal which is ***lateral to the pubic tubercle***. In contrast, an inguinal hernia passes through the superficial inguinal ring that lies ***medial to the pubic tubercle.***
- The coverings of a direct inguinal hernia are as follows:
  - In a lateral direct hernia they are (from deep to superficial) are:
    - Extraperitoneal tissue,
    - Fascia transversalis,
    - Cremasteric fascia,
    - External spermatic fascia and
    - Skin.
- In a medial direct hernia, the coverings are the same as given above except that the cremasteric fascia is replaced by the conjoint tendon which lies in the posterior wall of the medial part of the inguinal canal.

contd…

Clinical Correlation *contd...*

Umbilical Hernia

- At an early stage in embryonic life some coils of intestine project out of the abdominal cavity, constituting a ***physiological umbilical hernia***. After some time these coils return to the abdominal cavity and the gap at the umbilicus is gradually closed. In some cases, a child may be born with coils of intestine projecting out of the umbilicus. This is caused by failure of the physiological hernia to get reduced. The coils are not covered by peritoneum. They are covered by amnion to which the umbilical cord is attached. This condition is called ***congenital umbilical hernia***, ***exomphalos***, or ***omphalocoele***.
- Even in later life the umbilicus represents an area of weakness.
  - In some infants, a small protrusion of peritoneum may take place in the region resulting in a small swelling. This is called ***acquired infantile umbilical hernia***.
  - An ***acquired umbilical hernia*** may also be seen in old people (especially in women) in whom the abdominal muscles have become weak. Such herniae are really paraumbilical and lie to one side of the umbilicus.

Other Midline Herniae

- The linea alba is widest in its upper part. A midline protrusion through the linea alba anywhere above the umbilicus is called an ***epigastric hernia***.
- Below the level of the umbilicus, the region of the linea alba is narrow and is strengthened by close approximation of the right and left rectus muscles. However, in women whose abdominal muscles have become very weak as a result of repeated pregnancies a hernia may take place in the midline. As it increases in size, it pushes the rectus muscles apart creating a condition called ***divarication of recti***.

Herniae of Other Types

- Abdominal contents may pass into the upper part of the thigh through the femoral canal constituting a ***femoral hernia***.
- Various types of diaphragmatic herniae may occur. They may be congenital or acquired.
- Other rare sites where herniation may occur are the lumbar region (inferior lumbar triangle), perineal (through the pelvic floor), obturator (through the obturator canal), gluteal (through the greater sciatic foramen) and sciatic (through the lesser sciatic foramen). Ischiorectal hernia is described in an earlier chapter.
- Hernia can also take place in the region of an operative incision (***incisional hernia***). This is more likely to occur in persons who are obese, who have abdominal distension, and in whom there is postoperative infection.

Multiple Choice Questions

1. The posterolateral boundary of the anterior abdominal wall is:
   a. Lateral border of quadratus lumborum
   b. Medial border of quadratus lumborum
   c. Transverse processes of the lumbar vertebrae
   d. Mid axillary line

2. The pectineal ligament is connected on its medial end to the:
   a. Lacunar ligament
   b. Inguinal ligament
   c. Pubic tubercle
   d. Iliopectineal eminence

3. Floor of inguinal canal is formed by the:
   a. Upper surface of inguinal ligament only
   b. Upper surface of inguinal ligament and lacunar ligament
   c. Anterior surface of inguinal ligament only
   d. Anterior surface of inguinal ligament and lacunar ligament

4. The two terminal branches of the internal thoracic artery are:
   a. Superior epigastric and musculophrenic arteries
   b. Inferior epigastric and musculophrenic arteries
   c. Superior epigastric and inferior epigastric arteries
   d. Superior epigastric and anterior intercostal arteries

5. The rectus sheath, above the level of the costal margin, is:
   a. Deficient posteriorly
   b. Deficient anteriorly
   c. Reinforced by fascia from intercostal muscles
   d. Thickened by endothoracic fascia

ANSWERS

1. a **2.** a **3.** b **4.** a **5.** a

Clinical Problem-solving

Case Study 2: A 64-year-old woman has an umbilical hernia. It is of the acquired variety.
- What would you call this hernia, in specific terms?
- Suggest the possible predisposing factors for such a hernia.

Case Study 2: A 57-year-old man has a direct inguinal hernia.
- What would be the position of the neck of hernia with relation to the deep inguinal ring and the inferior epigastric vessels?
- Enumerate the names of some of the herniae that you know of.
- Can you define a hernia?

(For solutions see Appendix).

Chapter 15

External Genitalia and Perineum

Frequently Asked Questions

- Write notes on: (a) Alcock's canal, (b) Perineal membrane, (c) Pudendal nerve.
- Write briefly on: (a) Anal triangle, (b) Urogenital diaphragm, (c) Ischiorectal fossa, (d) Perineal body, (e) Anococcygeal ligament, (f) Internal pudendal artery.
- Write detailed notes on: (a) Testis, (b) Epididymis, (c) Spermatic cord.

The external genitalia forms an integral part of the abdomen. It forms one of the ten zones/regions of abdomen. The external genitalia, though homologous, differs in the male and female.

MALE EXTERNAL GENITALIA

The scrotum and the penis are collectively called the male external genitalia.

Scrotum

Scrotum (Latin.scrotos=bag) is a pendulous fibromuscular sac which hangs below the pubic symphysis between the anteromedial aspects of thighs. It lodges the testis and lower part of spermatic cord in males and is analogous to labia majora of females. It is divided into right and left halves by a midline raphe which is continuous with the raphe on ventral surface of penis anteriorly and raphe on the perineum behind. The left half is at a slightly lower level to accommodate the greater length of left spermatic cord.

The layers of the scrotal wall include skin, dartos muscle, external spermatic fascia, the cremasteric fascia and the internal spermatic fascia.

The scrotal skin is thin, pigmented and rugose. It contains thin scattered hairs, numerous sweat glands and sebaceous glands.

Dartos muscle (Greek.dero=skin, dartos=skinned) is a subcutaneous involuntary muscle. At the median raphe it projects to the interior as scrotal septum, which divides the scrotal sacs into two compartments. Anteriorly, it is continuous with the superficial fascia of anterior abdominal wall. Posteriorly,it is continuous with the fascia of Colles of perineum. It is supplied by sympathetic nerves from superior hypogastric plexus.

External spermatic fascia is derived from the external oblique aponeurosis.

Cremasteric fascia contains cremaster muscle (Greek. kremaseter=suspender) which is the detached part of internal oblique muscle. The muscle spreads in scrotum as irregular U-shaped loops, held together by areolar fascia. The ascending limbs of the loops form a tendon and it is attached to the pubic tubercle and pubic crest.

Internal spermatic fascia is derived from the transversalis fascia.

Blood Supply

The scrotum is supplied by superficial and deep external pudendal branches of femoral artery, posterior scrotal branches of internal pudendal artery and cremasteric branch of inferior epigastric artery. Corresponding veins drain into great saphenous vein and internal iliac vein.

Lymphatic Drainage

Lymph vessels from the scrotum drain into superficial inguinal lymph nodes.

Nerve Supply

Anterior third of scrotum is supplied by the ilioinguinal nerve and genital branch of genitofemoral nerve(L1). The posterior two-third of scrotum is supplied by posterior scrotal branches of pudendal nerve and perineal branch of posterior femoral cutaneous nerve(S3).

Development

The scrotum is formed by the fusion of two genital swellings.

Clinical Correlation

- ***Sebaceous cysts:*** These cysts are more common in scrotum, since numerous sebaceous glands are present in scrotum
- ***Scrotal oedema:*** Scrotum is the most common site for oedema in blunt injury.
- ***Scrotal elephantiasis:*** In this condition, there is massive enlargement of scrotum due to the accumulation of interstitial fluid in the scrotal wall following the blockage of lymph vessels by filarial worms.

Penis

The penis is the male organ of copulation. It consists of two parts—an attached portion called ***root or radix*** and a free pendulous portion called ***body or corpus***.

Root of Penis

The root is situated in superficial perineal pouch. It consists of three masses of erectile tissue, ***two crura*** and ***bulb of penis*** (Fig. 15.1).

Each crus is attached to the inner aspect of ischiopubic ramus and is covered by ischiocavernosus muscle. When traced in front, the crura approximates and it is continued as corpora cavernosa on the dorsal part of body of penis.

The bulb is attached to the inferior aspect of perineal membrane. Superficially the bulb is covered by bulbospongiosus muscle (Fig. 15.2). The urethra after piercing the perineal membrane enters the upper surface of the bulb and forms an intrabulbar fossa. Traced in front, the bulb is continuous with the corpus spongiosum of penis. It lodges in the groove on the ventral surface of corpora cavernosa of the body of penis.

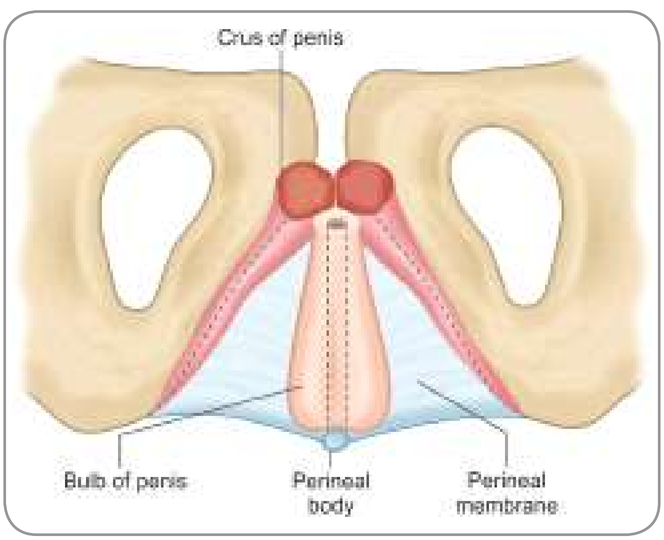
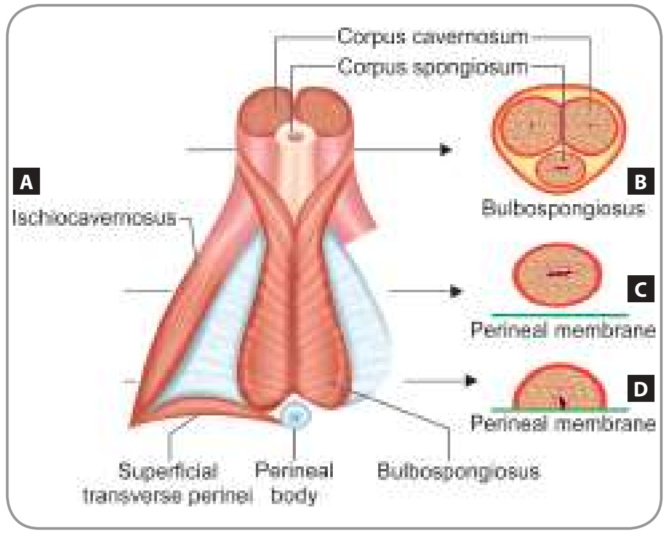


Fig. 15.1: Parts of the root of the penis lying on the perineal membrane



Figs 15.2A to D: A. Diagram to show muscles related to the root of the penis (**B** to **D**) are transverse sections at levels indicated in 'a'

Body of Penis

It is the free pendulous portion lying in front of scrotum. It consists of three fibro elastic cylinders. The upper and lower surfaces of the body of penis are described as dorsal surface and ventral surface respectively. A pair of ***corpora cavernosa*** on dorsal surface and unpaired ***corpus spongiosum*** (Fig. 15.3) on the ventral surface. In flaccid state, the corpus is cylindrical, which passes downwards and forwards making an angle with the root. During erection of penis, it is directed upwards and forwards. At the distal end of the body of penis, there is a conical expanded mass called the ***glans penis***. The ***glans penis*** is covered by a fold of skin called ***prepuce*** or ***foreskin*** (Fig. 15.4). The external urethral orifice is situated close to the tip of glans. When the prepuce is retracted from the glans, the base of the glans presents a raised margin called the ***corona glandis***. Just behind the corona glandis, there

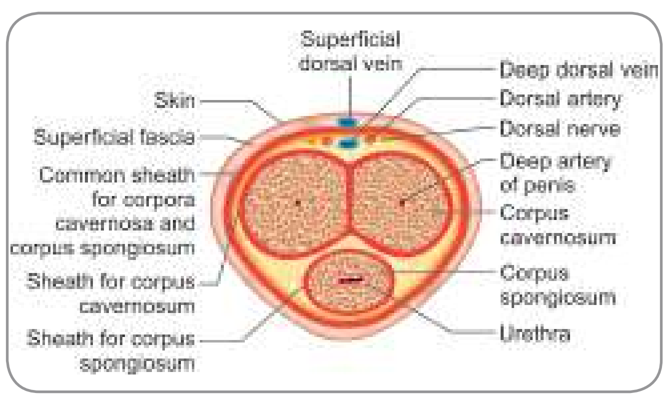


Fig. 15.3: Schematic cross-section through the free part of the penis

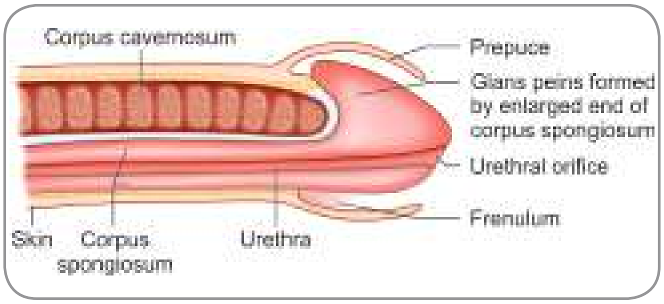


Fig. 15.4: Schematic parasagittal section through the penis

is a circular sulcus called the ***neck of penis***. Numerous sebaceous glands are present in the corona glandis and neck of penis, which secrete a material called ***smegma***. The potential space between the prepuce and glans is called ***preputial sac***. The glans is connected to the prepuce on its undersurface by a median fold called ***frenulum***. Frenulum extends from the base of glans to external urethral orifice.

The two corpora cavernosa are separated from each other by an incomplete vertical septum. Each corpora cavernosa is divided by a number of trabecular septa into numerous intercommunicating cavernous spaces. The cavernous spaces are lined by endothelium. They receive the blood from the helicine arteries. The helicine arteries are the branches of deep artery of the penis. These spaces are drained by deep dorsal vein of penis. In the flaccid state, the cavernous spaces remain empty. During erection the arterioles dilate and the spaces are filled with blood. As the spaces are distended, the venous outflow is diminished. So the penis becomes erect and turgid. The erection is purely a vascular phenomena.

Coverings of Penis

The coverings include the skin, superficial fascia and fibrous envelope.

Skin

Skin covering the penis is thin, hairless, loosely envelops the penis. At the neck of penis, the skin is reflected over the glans as a fold called ***prepuce***. A median raphe on ventral surface of penis indicates the fusion of two genital folds.

Superficial Fascia

Superficial fascia of penis is devoid of fat. The superficial dorsal vein lies in the midline.The fascia of penis or Buck's fascia forms the common covering for the three erectile masses. This fascia does not cover the glans. This fascia is continuous anteriorly with the Scarpa's fascia of anterior abdominal wall and posteriorly with dartos muscle of scrotum. This fascia is attached to pubic symphysis by suspensory ligament. The following structures lie deep to this fascia. Deep dorsal vein in the middle, flanked on either side by dorsal arteries. The dorsal nerves lie on the lateral aspects of the dorsal arteries.

Fibrous Envelope

Fibrous envelope known as tunica albuginea covers each mass of erectile tissue separately. From the inner surface of tunica albuginea, trabecular septa project within the corpora cavernosa and divide it into cavernous spaces.

Ligaments of Penis

The ligaments of penis suspend the body of penis from pubic symphysis.

- ***Fundiform ligament:*** This ligament is continuous with the linea alba above. Below, it splits into two layers which extends by the side of fascia of penis and thence becomes continuous with the septum of scrotum.
- ***Suspensory ligament:*** It is deep to the fundiform ligament and is triangular in shape. Its apex is attached to pubic symphysis and its base blends with the Buck's fascia on either side of body of penis.

Dissection

Identify the urethral opening at the tip of the glans penis. Identify the prepuce and the frenulum. Incise the skin of the penis proximal to the glans. Identify the dorsal vein, artery and nerve of penis. Examine the various fasciae. After making a transverse section of the shaft of penis, study the corpus spongiosum and corpora cavernosa. Examine the scrotum. Incise the skin and reflect. Identify the coverings of the cord and trace them to the testis.Look for the ductus deferens and identify. Trace it to the epididymis. Identify the epididymis and study its coiled nature. make necessary sections to study the details of the structure of testis and epididymis.

If a female cadaver is available, identify the following: Mons pubis, labia majora, labia minora, clitoris, vaginal orifice, openings of greater vestibular glands of Bartholin and the opening of the urehra.

Blood Supply (Fig. 15.3)

Arterial Supply

The penis is supplied by three paired arteries. Arteries to the bulb, deep and dorsal arteries. These arteries are the terminal branches of internal pudendal artery.

Arteries to the bulb supply the corpus spongiosum and spongy urethra.

Each deep artery pierces the crus penis and it passes through the corpus cavernosum. This artery divides into small branches in the trabecular septa. Some of these branches form helicine arteries which empty into the cavernous spaces.

Each dorsal artery of penis runs along the dorsal surface of penis, beneath the Buck's fascia and supplies the skin, prepuce and glans penis. It also supplies corpora cavernosum and corpus spongiosum.

Venous Drainage

The veins draining the penis are superficial and deep dorsal veins and they do not correspond to the arteries.

Superficial dorsal vein drains the prepuce and skin of penis. This vein runs backwards and drains into superficial external pudendal vein on either side or both sides.

Deep dorsal vein of penis drains the glans penis. It also receives the venous radicles from corpora cavernosum and some tributaries from corpus spongiosum. It drains into prostatic venous plexus. It also communicates with internal pudendal vein.

Lymphatic Drainage

The skin of the penis including prepuce drains into superficial inguinal nodes (upper medial group). The glans penis drains into the deep inguinal nodes and external iliac nodes. The erectile tissue and penile urethra into internal iliac nodes.

Nerve Supply

- Somatic innervation is by the dorsal nerve of the penis. These nerves supply the skin, prepuce and glans penis.
- The muscles of penis are supplied by the perineal branch of pudendal nerve.
- Parasympathetic nerves are derived from the pelvic splanchnic nerves (S2, S3 and S4). These nerves form prostatic plexuses. The postganglionic nerves from the plexuses form the cavernous nerves which supply the corpora cavernosum and corpus spongiosum. The Parasympathetics are vasodilators.
- Sympathetic nerves are derived from superior hypogastric plexus. They reach the penis via the pudendal nerves and their branches. The sympathetics are vasoconstrictors.

Erection and Ejaculation

In the performance of sexual act by the male partner two events, erection and ejaculation occur. These two events are the results of integrated action between the sympathetic and para sympathetic system.

Erection is a vascular phenomenon (which has been discussed earlier). The motor component is derived from the nervi erigentes (S2-S4) and cavernous nerves. The sensory component is derived from the glans penis via the dorsal nerves.

The ejaculation is stimulated by the sympathetic nerves which produce contraction of the vas deferens, seminal vesicles, ejaculatory ducts and prostate. At the same time the internal urethral orifice is closed preventing the reflux of semen into the bladder. The first lumbar segment is the spinal centre for ejaculation. At the end of ejaculation, the sympathetic nerves produce vasoconstriction and flaccidity of penis.

Development

Development of penis: It is developed from the elongation of genital tubercle.

Clinical Correlation

Congenital Anomalies of Penis

- ***Phimosis*** is the most common abnormality of the penis in which the prepuce is too narrow to be retracted. ***Circumcision*** is the surgical removal of prepucial skin. Circumcision is also practised as a religious ritual by Muslims and Jews.
- Other anomalies of the penis include partial or complete absence of penis, double or bifid penis and penis placed behind the scrotum.
- ***Hypospadias*** is a condition where the urethral opening is located anywhere on the undersurface of penis or in the perineum.
- ***Epispadias*** is a condition where the urethral opening is on the dorsal surface.

Testis and Epididymis

Testes (singular–testis) are a pair of male reproductive gonads which are suspended into the scrotum by the corresponding spermatic cords. The left testis is situated a little lower than the right. Testis is ellipsoidal in shape and compressed laterally. The average measurements of adult testis are 4–5 cm in length, 2.5 cm in breadth and 3 cm anteroposteriorly. The weight varies from 10.5 to 14 grams. Though some authors do not consider testis as a part of the external genitalia, it is discussed here because it is a constituent of the scrotum.

The testis has two poles or ends (upper and lower), two borders (anterior and posterior) and two surfaces (medial and lateral). Its upper pole is tilted anterolaterally and lower pole posteromedially (Fig. 15.5).

Upper pole of testis is overlapped by the ***head of epididymis***. It also gives attachment to ***appendix of testis*** (embryonic remnant of cephalic portion of mullerian duct). Lower pole of testis is connected to ***tail of epididymis*** (Fig. 15.6).

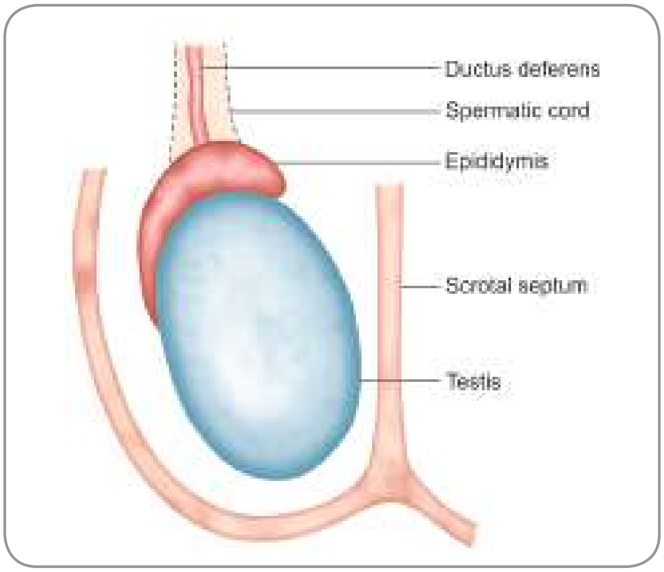


Fig. 15.5: Right testis seen from the front

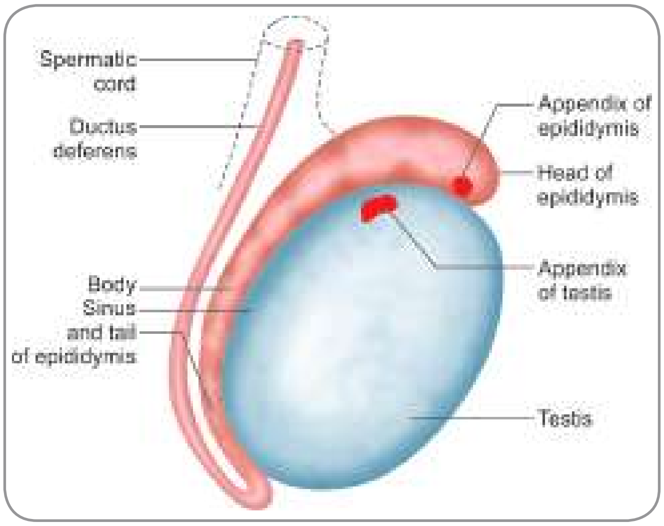


Fig. 15.6: Right testis seen from the lateral side

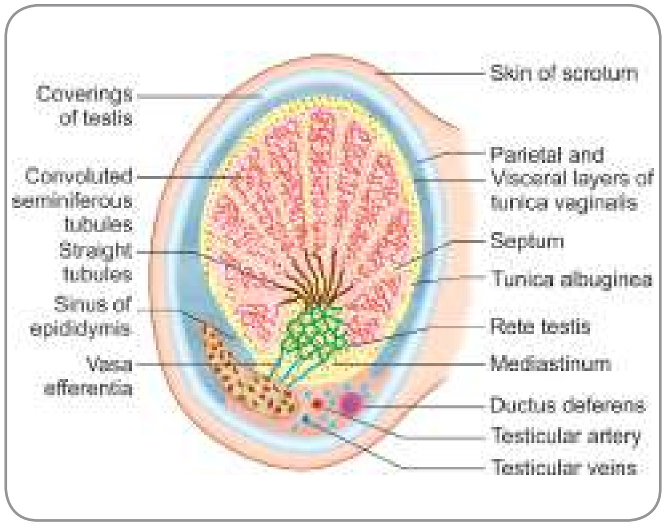


Fig. 15.7: Schematic transverse section through testis

Anterior border is convex. The posterior border is nearly straight with the vas deferens attached to it posteromedially and body of epididymis posterolaterally.

The medial and lateral surfaces are smooth and convex. Posterior aspect of lateral surface is overlapped by epididymis, which is separated from the testis by sinus of epididymis.

Epididymis is a comma shaped structure, situated along the lateral part of posterior border of testis. It consists of head, body and tail. The head is connected to upper pole of testis by efferent ductules and the tail is connected to lower pole by loose connective tissue. On the epididymal head is a small appendage called ***appendix of epididymis*** (mesonephric vestige). The head is formed by coiling of efferent ductules. These ductules join together to form the duct or canal of epididymis. Body and tail is formed by the coiling of this duct. This duct continues as vas deferens from the tail of epididymis.

The testis has three coverings from outside inwards—***tunica vaginalis***, ***tunica albuginea*** and ***tunica vasculosa*** (Fig. 15.7). The tunica vaginalis consists of two layers, ***visceral layer*** and ***parietal layer***. The visceral layer covers all the aspects of testis except most of the posterior aspect. Posteromedially, it is reflected forwards to the parietal layer, posterolaterally, it is recessed between lateral surface of testis and epididymal body forming sinus of epididymis. This layer then goes laterally to the posterior border of epididymis to become continuous with parietal layer. These two layers form a closed vaginal sac.

Tunica albuginea is bluish white, thick fibrous membrane. It covers the entire testis. At the posterior border, it projects into the interior of testis as vertical incomplete septum called ***mediastinum testis***. Numerous fibrous septae arise from the front and sides of the mediastinum testis, radiate towards the surface of testis. These septae divide the testis into cone shaped compartments called ***lobules of testis***. Each testis contains 200 to 300 lobules.

Tunica vasculosa lines the individual lobule of testis. It contains plexus of blood vessels and loose areolar tissue

Histology

Histology of Testis

Each lobule is roughly conical, the apex of the cone being directed towards the mediastinum testis. Each lobule contains one to three seminiferous tubules which are concerned with the production of spermatozoa. The Interstitial cells of Leydig lies in the loose areolar tissue between the seminiferous tubules. It produces male sex hormone testosterone and probably oestrogen.

Each seminiferous tubule has convoluted part in front and straight part behind. The straight part ascend in the mediastinum and join with adjacent tubules to form plexiform network of tubules known as ***rete testis***. About 12 to 20 efferent ductules arise from the upper end of rete testis and enter into the head of epididymis. Each ductule forms a cone shaped coiled mass, the lobule of epididymis. The efferent ductules unite to form a single duct called the ***canal of epididymis***. This canal is convoluted and it forms the body and tail of epididymis. The canal of epididymis continues as vas deferens from the tail, which ascends upwards behind the testis and medial to epididymis.

Microscopic Features

Each seminiferous tubule is covered by basement membrane, lined internally by spermatogenic cells and supporting cells of sertoli. The spermatogenic cells are arranged in three ill-defined zones. Outer zone consists of spermatogonia, intermediate zone consists of outer layer of primary spermatocytes and inner layer of secondary spermatocytes. Inner zone consists of two or more rows of spermatids. Sertoli cells are elongated polyhedral cells, that extend from the basement membrane to the lumen of seminiferous tubules. Interstitial cells of Leydig are situated within the lobule of testis, outside the seminiferous tubules.

contd...

Histology *contd...*

Rete testis are lined by flattened epithelium. Efferent ductules are lined by ciliated columnar epithelium. The canal of epididymis is lined by ciliated pseudo stratified columnar epithelium. The cilia are non-motile.

Arterial Supply

Testicular artery, a branch of the abdominal aorta is the main source of arterial supply. It is also supplied by artery to vas deferens (branch of superior or inferior vesical artery) and by cremasteric artery from inferior epigastric artery.

Venous Drainage

At the posterior border of testis and epididymis, 15 to 20 veins unite to form pampiniform plexus. At the superficial inguinal ring this plexus unites to form four veins. These four veins join to form two veins at deep inguinal ring which in turn join to form single vein in posterior abdominal wall. The right testicular vein drains into inferior vena cava at acute angle and the left into left renal vein at right angle.

Lymphatic Drainage

Lymph vessels from the testis drain into the pre-aortic and para-aortic lymph nodes.

Nerve Supply

The nerves are derived from the 10th and 11th thoracic segments of the spinal cord. They pass through the renal and aortic plexus and accompany the testicular vessels.

Development

Development of Testis

The genital ridge is formed on the dorsal body wall of embryo by the differentiation of coelomic epithelium during fifth week. The primordial germ cells from the endoderm of yolk sac migrate into the genital ridge during the sixth week. Under the influence of testis determining factor (TDF), indifferentiated gonad develops into testis. Numerous solid cords arise from the surface of genital ridge to the interior. Primitive sex cells are incorporated within the cords. Inner ends of the cords join together to form cellular plexus called ***rete cords***, which is situated close to the blind ends of the mesonephric tubules. All the components of testis (tunica albuginea, fibrous septa, seminiferous tubules, straight tubules, rete testis and sertoli cells) are derived from the genital ridge except spermatogonia which are derived from primordial germ cells. During the seventh month of intra uterine life, the testis cords and rete cords are canalised.

Efferent ductules of testis are developed from proximal persistent mesonephric tubules. These establish connections with the rete testis.

contd...

Development *contd...*

Descent of Testis

The testis develops in the abdominal cavity. It lies in the upper abdomen on the medial side of mesonephros. A peritoneal fold called processus vaginalis extends in front of the testis and reaches the scrotum. After the formation of processus vaginalis, a fibromuscular band called ***gubernaculum testis*** develops. This band connects the mesonephric duct and lower pole of testis to the base of scrotum. As the gubernaculum shortens, it pulls the testis along with processus vaginalis into which the testis projects from behind. At the fourth month of intrauterine life, testis appears in iliac fossa. At the seventh month, it reaches the deep inguinal ring. It traverses the inguinal canal during the eighth month. It reaches the scrotum at birth or slightly after birth.

Factors Responsible for the Descent of Testis

- ***Gubernaculum testis:*** Traction of gubernaculum widens the inguinal canal.
- ***Intra-abdominal pressure:*** Helps in rapid descent along the inguinal canal.
- Differential growth of body wall.
- ***Hormones:*** The interstitial cells of foetal testis secretes a hormone which organises the gubernaculum and is responsible for descent.

Clinical Correlation

- ***Incomplete descent of Testis/Cryptorchidism:*** The testis during its descent fails to reach the scrotum. It may be found within the abdomen,at the deep inguinal ring, within the inguinal canal,in the superficial inguinal ring or highup in the scrotum. Complications include failure of production of spermatozoa and the testis may be prone for malignant change.
- ***Ectopic testis:*** Instead of descending into the scrotum, the testis may travel along an abnormal path . It may come to lie under the superficial fascia of the anterior part of abdominal wall,under the thigh, in front of the pubis or in the perineum.
- ***Hydrocoele:*** It is the accumulation of fluid within tunica vaginalis, or any persisting part of the processus vaginalis. This condition is called hydrocoele.
- ***Varicocele:*** It is a condition where the pampiniform plexus of veins become tortuous and dilated (varicose) and form a palpable mass (like a bag of worms). It is more common on the left side, due to the following reasons; (a) The left testicular vein drains into the left renal vein at right angles,hence the venous pressure is high in left testicular vein, whereas the right vein drains at acute angle into the inferior vena cava. (b) compression of left testicular vein by loaded colon. Blockage of entry of left testicular vein by malignant tumour of left kidney.
- Infections can occur in epididymis (***epididymitis***), or testis (***orchitis***) or both (***epididymo-orchitis***).
- ***Torsion of testis:*** It is an emergency condition where the testis rotates around the spermatic cord within the scrotum. It is associated with severe pain.
- Seminoma and teratoma are two main varieties of testicular tumours.

Spermatic Cord

As the testis traverses the abdominal wall into the scrotum during early life, it carries its vessels , nerves and ductus deferens with it. These meet at the deep inguinal ring to form spermatic cord. It suspends the testis in the scrotum. The spermatic cord extends from the deep inguinal ring to the posterior aspect of testis. It is a tubular sheath about 7.5 cms in length, the left being slightly longer than the right. During the descent of the testis along the inguinal canal, the cord receives three tubular prolongations from the abdominal wall. Internal spermatic fascia from the fascia transversalis, cremasteric fascia and muscle from the internal oblique and external spermatic fascia (Fig. 15.8) from the external oblique aponeurosis.

The constituents of spermatic cord are:

- ***Vas deferens:*** Most important structure, passes along the posterior aspect of cord.
- ***Arteries:*** Testicular artery, cremasteric artery and artery to vas deferens.
- Testicular veins which are in the form of the pampiniform plexus.
- ***Nerves:*** Genital branch of genitofemoral nerve, cremasteric nerve and testicular sympathetic plexus.
- Lymph vessels of testis and epididymis.

Ductus Deferens/Vas Deferens

The ductus deferens is a thick walled muscular tube, about 45 cms in length. It begins from the tail of epididymis as the continuation of canal of epididymis. It passes upwards behind the testis, medial to the epididymis and reaches the superior pole of testis. From the superior pole, it ascends in the posterior part of spermatic cord to traverse the inguinal canal. At the ***deep inguinal ring*** (Fig. 15.9), it is separated from the spermatic cord. It turns medially by hooking around the inferior epigastric artery.

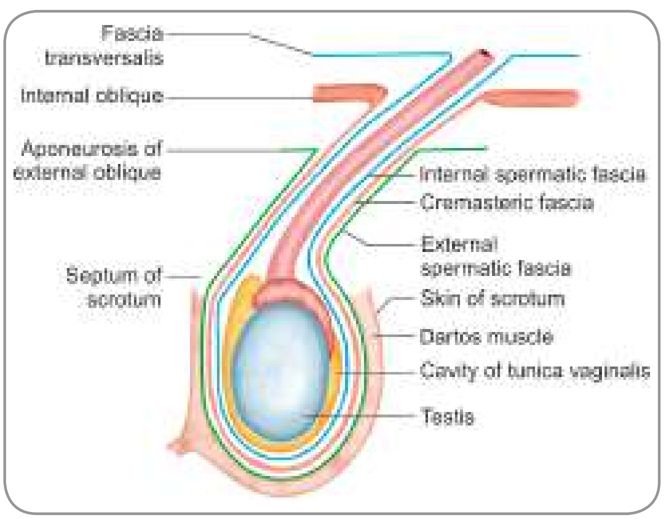


Fig. 15.8: Scheme to show the coverings of the spermatic cord and testis

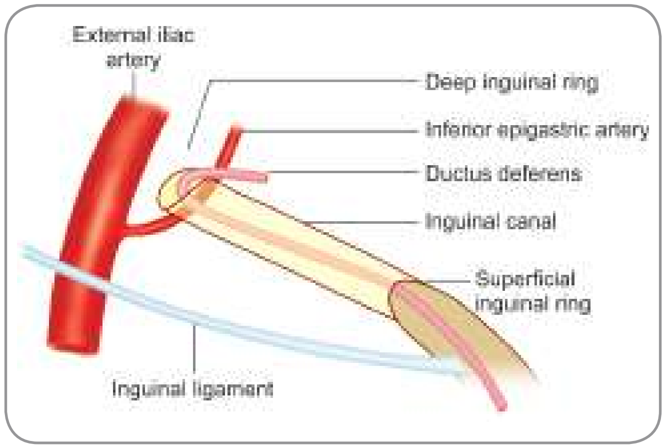


Fig. 15.9: Scheme to show relationship of ductus deferens to inferior epigastric artery. Also note relationship of the artery to the deep inguinal ring

It passes backward and medially across the external iliac vessels and enters the lesser pelvis. In the lesser pelvis, it runs downwards and backwards on the lateral pelvic wall crossing successively obliterated umbilical artery, obturator nerve and vessels. Then it passes above and medial to the terminal part of ureter and makes an angular bend downwards and medially. It passes behind the base of the urinary bladder, in front of the rectal ampulla and medial side of seminal vesicle. This part of the vas is dilated and is called ***ampulla***. Finally it joins with the duct of seminal vesicle to form ejaculatory duct. The ductus deferens has a very narrow lumen.

- ***Structure:*** The vas presents three coats from inside outwards mucous,muscular and areolar.
  The mucous membrane is lined by nonciliated simple columnar epithelium.
  The muscular coat consists of outer longitudinal and inner circular layers of smooth muscles.The serosa forms the outer most coat.
- ***Blood supply:*** Vas deferens is supplied by artery to vas, which is the branch of superior or inferior vesical artery. The veins from the vas joins the vesical venous plexus which in turn drains into internal iliac veins.
- ***Nerve supply:*** Rich autonomic plexus of sympathetic fibres supply it.

Clinical Correlation

Vasectomy: Bilateral ligation of vas deferens is called vasectomy. The right and left ductus deferens are approached through small incisions in the upper part of the scrotal wall, and are cut. The cut ends are ligated. It is one of the methods of family planning. After the operation, normal ejaculate doesnot contain sperms. The growth of interstitial cells is not affected, hence the testis continues to produce testosterone. So the potency of individual is unaffected. In case of need to revert back to normal, the two ends of the ductus deferens can be re-anastomosed. Nowadays conventional vasectomy is replaced by NSV, No Scalpel Vasectomy with no scar.

Seminal Vesicle

The two seminal vesicles are coiled, sacculated tubes located between the bladder and rectum. Each vesicle is pyramidal in shape, about 5 cm long, with its base directed upwards and posterolaterally. Each vesicle is a single coiled tube. The upper pole is cul-de-sac and the lower pole narrowing to form a straight duct, which joins with the vas deferens to form ejaculatory duct. They lie extraperitoneally at the base of the bladder and it lies lateral to the ampulla of vas deferens. Anterior surface is related to posterior surface of bladder. The posterior surface is related to ampulla of rectum, separated from it by rectovesical fascia. Laterally it is related to posterior true ligament of bladder containing vesical plexus of veins. The secretion of seminal vesicle is slightly alkaline and contains fructose, prostaglandin, choline and coagulating enzyme vesiculase.

- ***Structure:*** The wall of the vesicle consists of three coats from outside inwards-mucous membrane,muscular coat and external connective tissue. The mucous membrane is thrown into numerous folds and is lined by simple columnar epithelium with occasional goblet cell. The muscular coat consists of outer longitudinal and inner circular layers of smooth muscles. The serosa forms the outer most coat.
- ***Blood supply:*** Arterial supply is from inferior vesical artery and middle rectal artery.
  Corresponding veins and lymph vessels drain accompany the arteries.
  Nerves are derived from pelvic plexus.

Development

Each vesicle is developed from the caudal part of the mesonephric duct

Clinical Correlation

Seminal vesicles can be palpated per rectum. Abscess in the vesicle can rupture into the peritoneal cavity.

Ejaculatory Ducts

Each duct is about 2 cm long. It is formed by the union of vas deferens and the duct of seminal vesicle. It passes downwards and medially, posterolateral to the median lobe of prostate. It opens at colliculus seminalis,one on each side of the prostatic utricle.

The mucosa is lined by columnar epithelium. It is surrounded by outer circular and inner longitudinal layer of smooth muscle. The serosa forms the outer most coat.

FEMALE EXTERNAL GENITALIA

Female external genitalia is also called vulva or pudendum. It consists of mons pubis, labia majora, labia minora, clitoris, vestibule, vestibular bulb and greater vestibular glands (Fig. 15.10).

Mons pubis is a rounded median cutaneous elevation in front of pubic symphysis. This elevation is produced by subcutaneous fat. Coarse hairs are present over the skin of mons pubis.

Labia majora are two prominent fat filled longitudinal cutaneous folds. It extends from mons pubis to perineum. They bear crisp hairs on the outer surface and the inner surface is hairless. The two labia join in the front to form anterior commissure, posteriorly they meet indistinguishably at posterior commissure which overlies the perineal body. They form the lateral boundary for pudendal cleft into which the urethra and vagina open.

Labia minora are two thin folds of hairless skin located medial to labia majora. It is devoid of fat. The two labia minora are continuous anteriorly with the prepuce and frenulum of clitoris. Posteriorly the two labia minora unite to form frenulum of vestibule

Vestibule is a space between the labia minora. It contains the vaginal orifice, external urethral orifice, openings of two greater vestibular glands and numerous mucosal glands.

Clitoris is a structure homologous to penis, but it is not traversed by urethra. It consists of a pair of erectile tissue, the corpora cavernosa which diverges behind to form crus which is attached to pubic arch and is covered by ischiocavernosus muscle. The tip of the clitoris, glans is formed by the cephalic continuation of the bulbs of the vestibule. It is highly sensitive and is richly innervated by sensory receptors.

Bulbs of vestibule are a pair of elongated erectile tissue flanking the vagina. It is continuous in front with glans clitoridis. The bulbs are covered superficially by bulbo-spongiosus muscle.

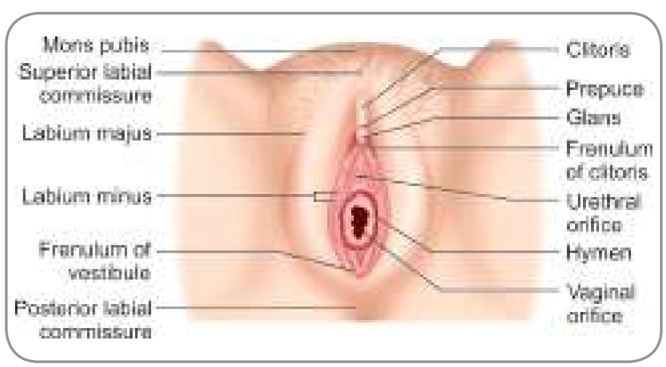


Fig. 15.10: Female external genitalia

Greater vestibular glands (Bartholin's glands) are mucous secreting glands situated behind the bulbs in superficial perineal pouch. The ducts open on each side in the vaginal orifice below the hymen.

The female external genitalia are supplied by the superficial and deep external pudendal branches of femoral artery, and by the labial branches of internal pudendal artery. Corresponding veins drain into great saphenous vein and internal iliac vein.

- ***Lymphatic drainage:*** Lymph vessels drain into superficial inguinal lymph nodes.
- ***Nerve supply:*** The nerves supplying the region are the ilioinguinal nerve, genital branch of genitofemoral nerve (L1), posterior labial branches of pudendal nerve and perineal branch of posterior femoral cutaneous nerve (S3).

Clinical Correlation

- The clitoris may be absent, double or bifid. It is enlarged in hermaphroditism (see below).
- The labia minora may show partial fusion.
- The female urethra may open on the anterior wall of the vagina instead of opening into the vestibule.
- Abnormal development of gonads and genitalia gives rise to various types of hermaphroditism.

PERINEUM

Perineum is the region below the pelvic diaphragm. It includes all the structures related to the pelvic outlet.

The perineum is bounded anteriorly by the pubic arch and arcuate ligament, laterally by the ischiopubic ramus, ischial tuberosity and sacrotuberous ligaments and posteriorly by the tip of coccyx.

An imaginary transverse line in front of ischial tuberosities divides the perineum into two triangles, urogenital triangle in front with its apex at pubic symphysis and anal triangle behind with its apex at coccyx. The urogenital triangle slopes downwards and backwards and contains external urogenital structures. The anal triangle slopes downwards and forwards and it contains anal canal.

UROGENITAL TRIANGLE (FIG. 15.11)

It is the anterior part of pelvic outlet. On the surface, this triangle presents penis and scrotum in male. In female, it presents female external genitalia and the orifices of urethra and vagina. Boundaries include pubic arch and arcuate ligament anteriorly, ischiopubic ramus laterally and imaginary transverse line in front of ischial tuberosities posteriorly.

Urogenital triangle has the following layers from below upwards—skin, fatty and membranous layer of superficial fascia, contents of superficial perineal pouch or space, perineal membrane, contents of deep perineal pouch or space, and superior fascia of urogenital diaphragm.

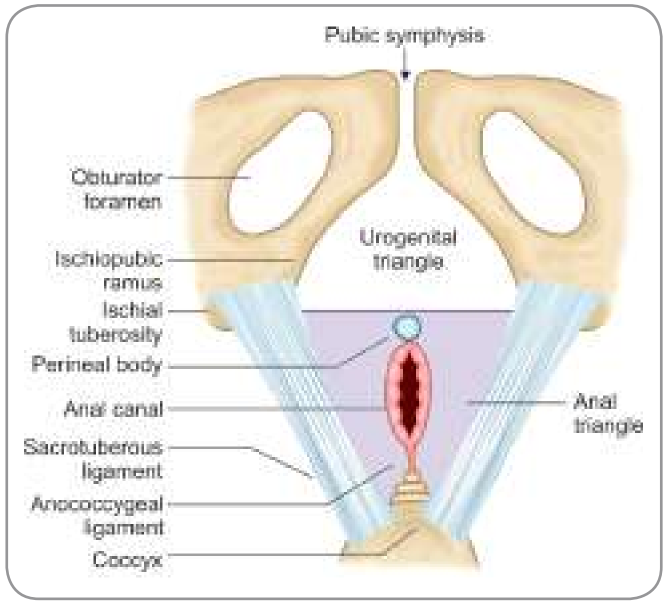


Fig. 15.11: Boundaries of the perineum

Skin

In male, the skin over this triangle presents a midline raphe, which is continuous with the median raphe of the scrotum. In female, the skin presents a median cleft, between two labia minora called the ***vestibule***. Urethra and vagina open into the vestibule.

Fatty and Membranous Layer of Superficial Fascia

Fatty layer of superficial fascia is continuous with subcutaneous tissue of adjacent areas. Membranous layer in the perineum is also called as ***Colles fascia***. It is a strong sheet of fascia, stretching across the pubic arch. It forms the lower boundary of superficial perineal pouch. Laterally, it is attached to the lower margin of ischiopubic ramus, posteriorly, it is attached to the posterior margin of perineal membrane. When traced anteriorly, it is continuous with the dartos muscle of scrotum, fascia of penis and with the fascia of Scarpa of anterior abdominal wall. The Colles fascia is pierced by the perineal branch of posterior femoral cutaneous nerve, the urethra and vagina (female).

Superficial Perineal Pouch/Space

It is an interfascial space, situated below the perineal membrane. It is closed on all sides except in front. It is bounded superiorly by the perineal membrane, inferiorly by the Colles fascia, laterally by the inner surface of ischiopubic ramus, the pouch is closed behind by the fusion of colles fascia with the perineal membrane.

Anteriorly, the pouch is open and it is continuous with the superficial inguinal space.

Contents of Superficial Perineal Pouch

- ***Three muscles on each side***
  - Transversus perinei superficialis
  - Bulbospongiosus
  - Ischiocavernosus
- ***Three vessels on each side***
  - Two posterior scrotal or labial vessels which are the branches of internal pudendal artery.
  - Transverse perineal vessels which arise either from scrotal or internal pudendal artery.
- ***Three nerves on each side***
  - Two posterior scrotal or labial branches of perineal nerve.
  - Perineal branch of posterior femoral cutaneous nerve.
- ***Other structures***
  - Crus penis or clitoridis, attached on either side to the ischiopubic ramus.
  - Bulb of penis in the male, traversed by spongy urethra
  - Urethra and vagina in female, Bulb of vestibule and greater vestibular glands are present on either side of vagina

Muscles of Superficial Perineal Pouch (Fig. 15.12)

- ***Transversus perinei superficialis:*** It is a narrow muscular strip which arises from the anterior and medial aspects of ischial tuberosity. It is inserted mainly into the perineal body. Some fibres are inserted into the ipsilateral bulbospongiosus or sphincter ani externus. In the perineal body its fibres decussate and pass to the contralateral transversus perinei or bulbospongiosus or sphincter ani externus.
  - ***Nerve supply:*** Muscular branch of perineal nerve
  - ***Action:*** It fixes the perineal body.
- ***Bulbospongiosus:*** In males, this muscle covers the bulb of penis and the two symmetrical halves are united by a median fibrous raphe. It arises from the perineal body and midline raphe. Posterior fibres are dispersed on the perineal membrane. Middle fibres encircle the penile bulb and adjacent corpus spongiosum and form an aponeurosis where they meet with the fibres of opposite side. Anterior fibres cover the dorsal surface of corpora cavernosa and form an aponeurosis superficial to the deep dorsal vein of penis.
  In females, the two halves split to embrace the vaginal orifice and covers the bulb of the vestibule and greater vestibular glands. It arises only from the perineal body. The fibres passes forwards on each side of vagina and end in an aponeurosis on the dorsal surface of corpora cavernosa clitoridis. These fibres lies superficial to deep dorsal vein of clitoris.
  - ***Nerve supply:*** Muscular branch of perineal nerve
  - ***Actions:*** This muscle compresses the deep dorsal vein and helps in the erection of penis or clitoris.
    - In males, it helps to expel the drops of urine from the urethra and contracts repeatedly in ejaculation.
    - In females, it constricts the vaginal orifice and helps in expression of secretions from greater vestibular glands.
- ***Ischiocavernosus:*** It arises from the inner surface of ischiopubic ramus and is inserted into the sides and undersurface of penis or clitoridis.
  - ***Nerve supply:*** Muscular branch of perineal nerve.
  - ***Action:*** It compresses the cavernous spaces of crura and impedes the venous return and there by maintains the erection of penis or clitoridis.

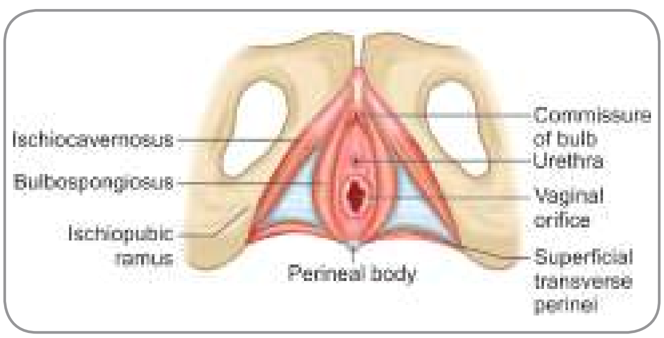


Fig. 15.12: Muscles present in the superifcial perineal space in the female

Added Information

Conventionally, the perineal pouches have been described as superficial and deep perineal pouches. However, a newer concept has been now described which is discussed later. Before discussing the perineal pouches, a review of the fascia of the perineal region is done.

- ***Superficial perineal fascia:*** The Colles' fascia which lies just below the skin is called the superficial perineal fascia.
- ***Deep perineal fascia:*** The deep perineal fascia is the layer of fascia that invests the superficial perineal muscles and is attached firmly to the ischiopubic rami, posterior margin of perineal membrane and perineal body. In front , it fuses with the suspensory ligament of penis.
- ***Perineal membrane:*** The perineal membrane is a triangular membrane which stretches horizontally between the ischiopubic rami. It was formerly called the inferior fascia of urogenital diaphragm.
- ***Endopelvic fascia:*** The pelvic fascia that invests the pelvic viscera is called the endopelvic fascia.

According to the current concept, the urogenital diaphragm is no longer considered to be a separate entity and does not exist.

contd…

Added Information *contd...*

Hence, in view of the above description of the fasciae in the perineal region, three perineal pouches are described namely, subcutaneous perineal pouch, superficial perineal pouch and deep perineal pouch.

- ***Subcutaneous perineal pouch:*** The subcutaneous perineal pouch lies between the deep perineal fascia and the superficial perineal fascia. It is a potential space and can be filled with fluid in abnormal conditions. The attachments of both the fasciae are firm in both lateral and posterior aspects and hence any collection of fluid tends to extend anteriorly along the superficial fascia of scrotum/labia majora and thence even onto the anterior abdominal wall.
- ***Superficial perineal pouch:*** The superficial perineal pouch is between the perineal membrane and the deep perineal fascia. In fact only the superficial perineal muscles (ischiocavernosus, bulbospongiosus and the corpora of the penis) along with the branches of the pudendal nerves and vessels occupy this space. In males, additionally it is traversed by the penis and in females, it is crossed by the urethra, vagina and contains clitoris. It is totally a closed space and any injury to the contents will be confined within unless there is a breach in the limiting fasciae. The subcutaneous pouch and superficial perineal pouch together constituted the superficial perineal pouch in the earlier concept and hence the superficial perineal muscles were included as its content. But clinical textbooks still consider the subcutaneous pouch as the superficial perineal pouch.
- ***Deep perineal pouch:*** The deep perineal pouch is the space above the perineal membrane. It does not have a definite upper limit and is bounded by the endopelvic fascia of the pelvic floor above. According to the earlier concept, the principal content was supposed to be the urethra and the urethral sphincter (which surrounds the urethra), but it is now considered that the urethral sphincter is a part of the urethra itself. Its fibres may even extend up to the neck of the bladder. The sphincter urethrae, compressor urethrae, sphincter urethra vaginalis present in this space have been already discussed above. Also present within this space are the deep transverse perinei muscles. These muscles do not form a true diaphragmatic sheet as such because fibres from several parts extend through the visceral outlet of the pelvic floor into the pelvic cavity above.

Perineal Membrane

It is a strong triangular sheet of fascia which separates the deep perineal pouch above and superficial perineal pouch below. In males this membrane is tough due to the attachment of root of penis and associated perineal muscles. Anteriorly, it is thickened to form transverse perineal ligament and is continuous with the superior fascia of urogenital diaphragm. Laterally, it is attached to the ischiopubic ramus above the attachment of crus penis. Posteriorly, it is attached to the perineal body, where it splits into two layers. Upper layer is continuous with the superior fascia of urogenital diaphragm and the lower layer is continuous below with the Colles fascia.

In female, the membrane is divided into two halves by vagina and urethra. It is less tense and less well defined. Since there is no transverse perineal ligament in females, it is continuous anteriorly with pubourethral ligament.

The perineal membrane is perforated by the following structures:

- Urethra 2–3 cm behind the pubic symphysis
- Ducts of bulbourethral glands near urethra
- Arteries and nerves to the bulb of penis/clitoris
- Deep arteries of the penis/clitoris, near the middle of its attached margin
- Dorsal artery of penis or clitoris, near its apex
- Posterior scrotal vessels/labial vessels and nerve near the base
- Vagina in female, behind the urethra.

Deep Perineal Pouch

It is an interfascial space above the perineal membrane. It is closed on all sides.

Boundaries

This space is bounded superiorly by the superior fascia of urogenital diaphragm, inferiorly by the perineal membrane (inferior fascia of urogenital diaphragm), anteriorly by the transverse perineal ligament, posteriorly by the fusion of perineal membrane with the superior fascia of urogenital diaphragm and laterally by the inner surface of ischiopubic ramus.

Contents

- ***Muscles (males) (Fig. 15.13):*** Deep transverse perinei or transversus perinei profundus and sphincter urethrae

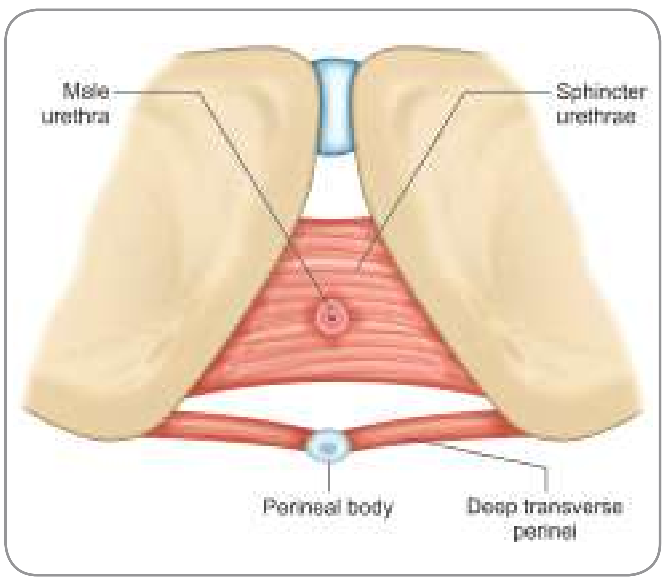


Fig. 15.13: Muscles present in deep perineal space (as seen in the males)

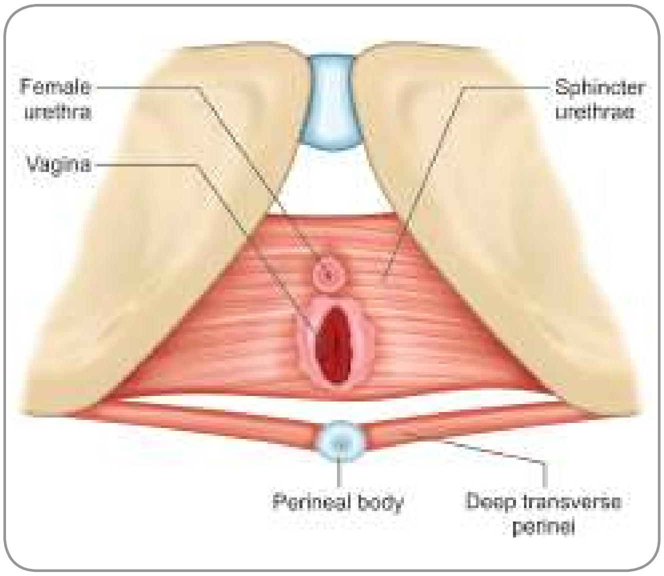


Fig. 15.14: Muscles present in deep perineal space (as seen in the female)

- ***Muscles (females) (Fig. 15.14):*** Sphincter urethrae, compressor urethrae and sphincter urethrovaginalis
- ***Vessels:*** Internal pudendal artery and its three terminal branches—deep artery of penis or clitoris, dorsal artery of penis or clitoris and artery to the bulb of penis or vestibule.
- ***Nerve:*** Dorsal nerve of penis or clitoris
- Membranous urethra
- ***Bulbo-urethral*** gland and its duct in male
- Vagina, behind urethra in females.

UROGENITAL DIAPHRAGM

It is a musculofascial partition formed by two muscles, deep transverse perinei and sphincter urethrae and the two fasciae enclosing it namely the superior and inferior fascia of urogenital diaphragm.

Muscles (Males)

- ***Deep transverse perinei or Transversus perinei profundus:*** It extends from the medial aspect of ischial ramus to perineal body. These fibres decussate with its contralateral counterpart, deep part of sphincter ani externus behind and sphincter urethrae.
  - ***Nerve supply:*** Muscular branch of perineal nerve.
  - ***Action:*** Along with superficial transverse perinei, this muscle tether the perineal body and keep the visceral canals in median plane.
- ***Sphincter urethrae:*** It consists of inferior fibres and superior fibres. The inferior fibres encircle the membranous urethra, some of its fibres after encircling attach to inner surface of inferior ramus and other fibres continue into the prostate. Superior fibres form horse shoe, their dorsal ends merge with the smooth muscle of bladder, ventrally the fibres merge into prostate.
  - ***Nerve supply:*** Muscular branch of perineal nerve. It may also receive innervation via pelvic splanchnic nerves.
  - ***Action:***
    - When the bladder is distended, it compresses the urethra.
    - It is relaxed during micturition.
    - It contracts to expel the final drops of urine or semen (males) from the membranous urethra.

Muscles (Females)

- ***Sphincter urethrae:*** It surrounds more of the middle third of urethra. Above, it blends with the smooth muscle of bladder neck and below, it blends with the lower part of urethra.
- ***Compressor urethrae:*** It arises from the ischiopubic rami of each side. These fibres pass forwards and meet its fellow of opposite side ventral to the urethra and below the sphincter urethra. Some fibres pass medially and reach the vagina.
- ***Sphincter urethrovaginalis:*** It arises from the perineal body,its fibres pass forwards on either side of vagina and urethra. It meets its counterpart ventral to urethra below the compressor urethrae.
  - ***Nerve supply:*** Muscular branch of perineal nerve. It may also receive innervation via pelvic splanchnic nerves.
  - ***Action:*** These three muscles play an important role in continence of urine.

Fasciae of Urogenital Diaphragm

- Superior fascia of urogenital diaphragm.
  It is attached to the inner surface of ischiopubic ramus on either side and becomes continuous with obturator fascia. When traced anteriorly and posteriorly, it blends with the perineal membrane and closes the deep perineal pouch. It is also reflected by the side of urethra in the midline to become continuous with inferior fascia.
- Inferior fascia of urogenital diaphragm, also called the ***perineal membrane*** has been discussed.

Structures Piercing the Urogenital Diaphragm

- Urethra
- Vagina in females, behind the urethra

Relations of Urogenital Diaphragm

Above, it is related to apex of prostate in males and bladder neck in females, anterior fibres of both levator ani and anterior recesses of ischiorectal fossae. Below, it is related to contents of superficial perineal pouch. Anteriorly it is related to deep dorsal vein of penis or clitoris and dorsal nerve of penis or clitoris on either side of the vein. These structures pass through the triangular gap between the arcuate pubic ligament and transverse perineal ligament. Behind it is related to ischiorectal fossae and their contents.

Actions of Urogenital Diaphragm

- It supports the prostate (males) and bladder.
- It fixes the perineal body.
- It constricts the vagina (females).
- Sphincter urethrae exerts voluntary control of micturition. It contracts to expel the final drops of urine or semen(males) from the membranous urethra.

ANAL TRIANGLE

The boundaries of the anal triangle are—an anteriorly imaginary transverse line in front of ischial tuberosities, laterally the sacrotuberous ligaments and posteriorly the tip of coccyx. It contains the anal orifice surrounded by sphincter ani externus anteriorly and anococcygeal ligament posteriorly. On either side of anal orifice, there is a wedge shaped space called as ***ischiorectal fossa*** or ***ischioanal fossa***.

- ***Superficial fascia:*** This fascia is thick and areolar and contains a pad of fatty tissue which extends deeply into ischiorectal fossa.
- ***Deep fascia:*** This fascia lines the ischiorectal fossa. It comprises the inferior fascia of pelvic diaphragm and the part of obturator fascia below the attachment of levator ani.

Ischiorectal Fossa/Ischioanal Fossa

It is a fat filled wedge shaped space on each side of anal canal. The fat allows the distension of anal canal during defecation.

- ***Measurements:*** Vertically–5 cm, anteroposteriorly–5 cm and transversely–2.5 cm respectively.
- ***Boundaries:*** The fossa has an apex, base, lateral wall, medial wall, anterior wall and posterior wall. The apex is directed upwards and is formed by fusion of anal and obturator fascia. The base is directed downwards and is formed by skin and superficial fascia. The lateral wall is vertical and is formed by obturator fascia, obturator internus muscle and ischial tuberosity. The base is formed by levator ani above and sphincter ani externus below. Anteriorly it is related to deep transverse perinei, perineal membrane and superficial transverse perinei from above downwards. Posteriorly, it is related to sacrotuberous ligament and lower margin of gluteus maximus.

Recesses are narrow extensions of boundaries. This fossa has an anterior and a posterior recess. Anteriorly this fossa extends above the urogenital diaphragm as far as the body of pubis to form anterior recess. Posterior recess is the backward extension of the fossa to the side of coccyx between the sacrotuberous and sacrospinous ligaments.

- ***Fascial relations:*** Obturator fascia lines the lateral wall of fascia. Anal fascia lines the medial wall. Lunate fascia is arranged in an arched manner and lines the deepest part of the fossa. Its summit is called the ***tegmentum***. Perianal fascia is an extension from the lower end of conjoint longitudinal tendon in anal wall.

Lunate fascia and perianal fascia divide the fossa into three compartments. Supra tegmental space (space above tegmentum) containing loose fat, ***ischiorectal space*** filled with fat and traversed by fibrous tissue and perianal space containing loculated fat.

Pudendal Canal/Alcock's Canal (Fig. 15.15)

It is a fascial tunnel in the lateral wall of the ischiorectal fossa. It extends from the lesser sciatic foramen to the posterior limit of deep perineal pouch. This canal is formed either by splitting of obturator fascia or by separation of obturator fascia and lunate fascia.

Contents of the canal include internal pudendal vessels and pudendal nerve. This nerve divides within the canal into dorsal nerve of penis and perineal nerve.

Contents of Ischiorectal Fossa

- Ischiorectal pad of fat, which occupies the entire fossa.
- Internal pudendal vessels and pudendal nerve in pudendal canal.
- Inferior rectal vessels and nerve cross the middle of fossa from lateral to medial.
- Posterior scrotal (labial) vessels and nerve are seen in the anterior part of the fossa.
- Perineal branch of 4th sacral nerve is seen in the posterior part of fossa.

Clinical Correlation

- ***Ischiorectal abscess***
  - The ischiorectal fossa is vulnerable to infection because of the presence of poorly vascularised fat in the fossa. Infections can reach the fossa from the anal canal, from overlying skin of the perineum and, occasionally, by downward rupture of a pelvirectal abscess (through the levatorani). The right and left ischiorectal fossae communicate with each other posterior to the anal canal, and infection can pass from one fossa to the other (Horse shoe shaped abscess).
  - Bursting of an ischiorectal abscess on to the perineal skin results in a sinus. Anal fistula (ischiorectal type) is formed, if this abscess bursts into the anal canal.

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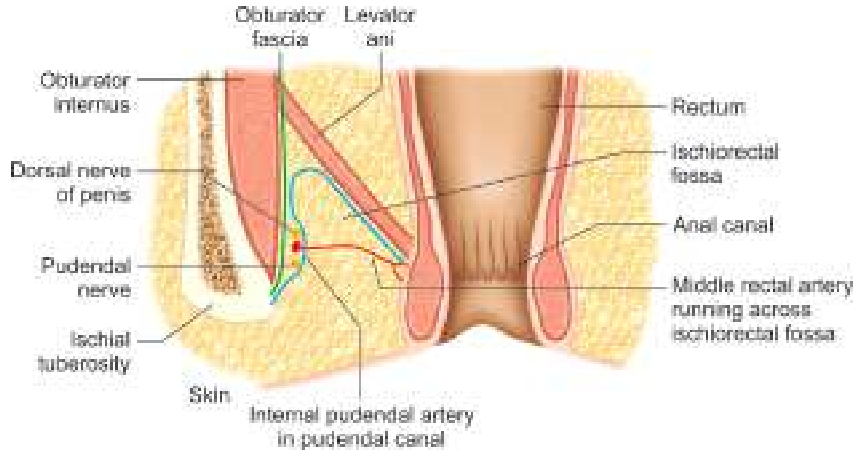


Fig. 15.15: Section through the ischiorectal fossa and the pudendal canal

Clinical Correlation *contd...*

- Abcess in the perianal space produces tremendous pain due to tension and it may burst through peri-anal skin.
- ***Ischiorectal hernia:*** The hiatus of Schwalbe is a gap that may exist between the obturator fascia and the origin of the levator ani from it (i.e., in relation to the apex of the ischiorectal fossa). Pelvic contents can herniate through this hiatus constituting an ischiorectal hernia.

- ***Sphincter ani externus:*** It is dicussed in detail in the chapter on pelvic viscera.

ANOCOCCYGEAL LIGAMENT

It is a musculotendinous structure lying in midline, between the rectum and anus anteriorly and coccyx posteriorly. It forms a postanal plate with the overlying presacral fascia. This fascia supports the terminal rectum. From above downwards, its attachments are—(a) presacral fascia, (b) tendinous plate of pubococcygeus, (c) muscular raphe of iliococcygeus, (d) posterior attachment of puborectalis and (e) sphincter ani externus.

Action: Elevation of postanal plate reduces the anteroposterior length of ano-urogenital hiatus.

PERINEAL BODY

Perineal body (Latin-centrum tendineum perinei) is a pyramidal fibromuscular node placed in the median plane at the junction of the anal and urogenital triangles. It is 1.25 cm in front of anal margin and close to the bulb of penis in male and close to the posterior wall of vestibule of vagina in female. Its apex receives the attachment of rectovesical (rectovaginal) septum. Below the apex, the muscles and their fascia converge in it.

The muscles attached to it from above downwards are as follows:

- Smooth muscle of sphincter ani internus and conjoint longitudinal coat of rectum.
- Two levatores prostatae (pubovaginales).
- Deep perineal muscles which includes sphincter urethrae, two deep transverse perinei and deep part of sphincter ani externus.
- Superficial perineal muscles which includes bulbospongiosus, two superficial transverse perinei and superficial part of sphincter ani externus.

It is an extremely important structure in females. Stimulation of the perineal body causes the pelvic floor as a whole to contract. It maintains the integrity of pelvic diaphragm and provides support to pelvic organs.

Clinical Correlation

- Perineal body may be torn during parturition in females. If it is not properly repaired, the hiatus urogenitalis becomes wider. Through this gap, pelvic viscera may be displaced downwards producing prolapse of uterus.
- Episiotomy is a simple surgical procedure done in the third stage of labour to facilitate the passage of foetal head through the vaginal orifice. It also avoids irregular tears in the perineum.

INTERNAL PUDENDAL ARTERY

The internal pudendal artery is one of the two terminal branches of anterior division of internal iliac artery. It begins within the pelvic cavity. It leaves the pelvis through the greater sciatic foramen along with pudendal nerve and nerve to obturator internus to enter the gluteal region between piriformis and coccygeus muscle. It crosses the

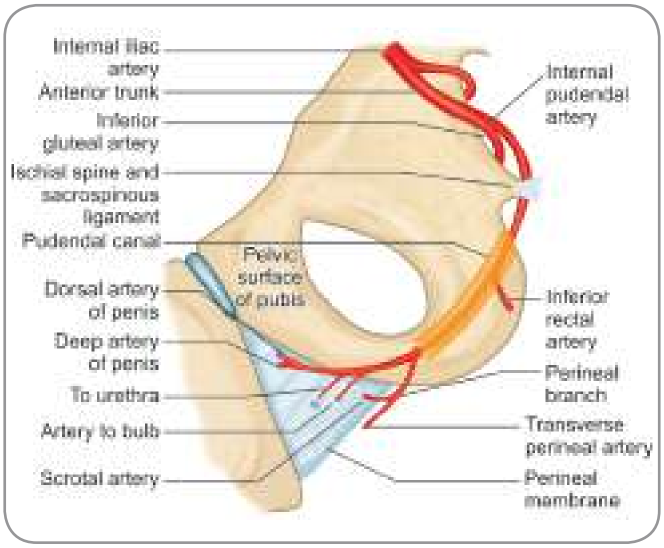


Fig. 15.16: Scheme to show course and branches of the internal pudendal artery

dorsal surface of the ischial spine and leaves the gluteal region through the lesser sciatic foramen to enter into the perineum along with the pudendal nerve. The artery and the pudendal nerve then traverse the pudendal canal on the lateral wall of the ischiorectal fossa. At the anterior end of this canal it lies between the two terminal branches of the nerve (perineal nerve and dorsal nerve of penis) and appears in the deep perineal pouch. It runs forwards along the ischiopubic ramus where it divides into two terminal branches, deep and dorsal artery of penis or clitoris.

The branches of the artery are as follows (Fig. 15.16):

- The inferior rectal artery arises in the pudendal canal. This branch runs medially through the ischiorectal fossa to supply the structures in the perianal region.
- The perineal branch arises near the anterior end of the pudendal canal. It pierces the perineal membrane and enters the superficial perineal pouch. It gives off transverse perineal artery and two posterior scrotal or labial arteries.
- The artery to the bulb of penis or vestibule is given off in the deep perineal space. It pierces the perineal membrane and supplies the erectile tissue of bulb and corpus spongiosum of penis in male and bulb of vestibule and vagina in female.
- Urethral artery pierces the perineal membrane and supplies the urethra upto glans penis.
- The deep artery of the penis or clitoris pierces the perineal membrane enters the crus penis or clitoris and to supply the erectile tissue of corpus cavernosum.
- The ***dorsal artery of penis*** (Fig. 15.17) or clitoris pierces the perineal membrane enters the suspensory ligament to reach the dorsum of penis or clitoris. Here it is accompanied by deep dorsal vein medially and dorsal nerve laterally. It supplies the prepuce and glans and provides numerous branches which anastomose with deep artery of penis.

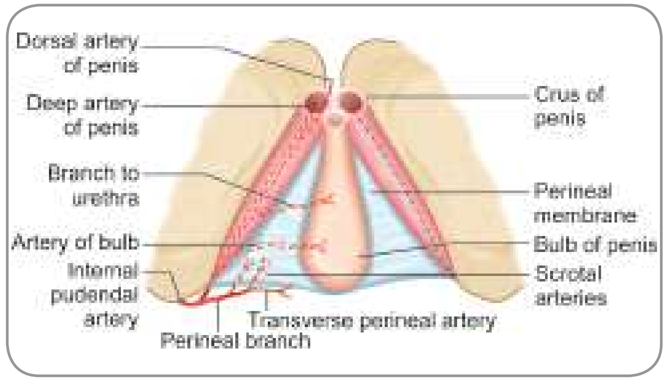


Fig. 15.17: Terminal part of internal pudendal artery as seen in the male perineum (viewed from below)

INTERNAL PUDENDAL VEIN

Veins draining the penis and scrotum in male and external genitalia in female join to form internal pudendal vein which accompany the internal pudendal artery. This vein communicates with prostatic venous plexus in male and vesical venous plexus in female. It drains into internal iliac vein.

PUDENDAL NERVE

The pudendal nerve is the chief nerve of perineum. It arises from the ventral rami of S2, S3 and S4 in the pelvis. The nerve leaves the pelvis through the greater sciatic foramen below the piriformis muscle. It crosses the dorsal surface of ischial spine medial to the internal pudendal vessels and nerve to obturator internus. Through the lesser sciatic foramen, the nerve enters the pudendal canal (Fig. 15.18) along with internal pudendal artery which lies inferior to

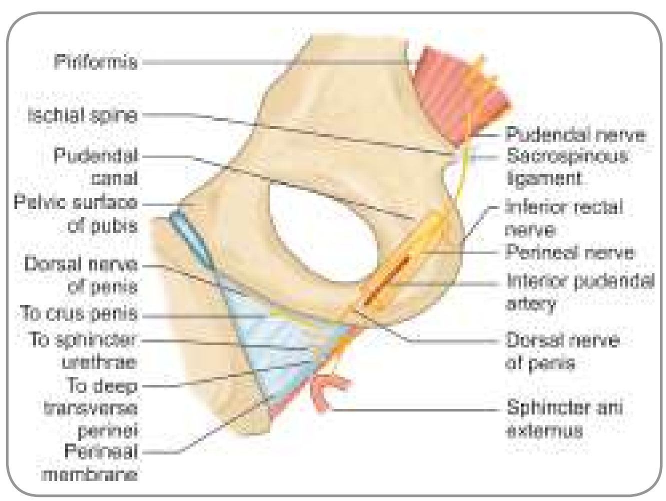


Fig. 15.18: Scheme to show the course and distribution of the pudendal nerve

it. It gives off inferior rectal branch. In the anterior part of canal, the nerve divides into perineal nerve and dorsal nerve of penis (or clitoris).

Branches of the Pudendal Nerve

- The inferior rectal nerve accompanies the corresponding vessels and traverses the ischiorectal fossa from lateral to medial side. It supplies the sphincter ani externus, peri-anal skin and anal canal up to the pectinate line and lower 2.5 cm of vagina.
- The perineal nerve is the larger terminal branch of the pudendal nerve. In the anterior end of pudendal canal, it divides into two posterior scrotal or labial branches and muscular branches.
  - The posterior scrotal or labial branch pierces the perineal membrane and enters the superficial perineal pouch. It supplies the skin of the posterior two-third of scrotum or labium majus.
  - The muscular branch supplies the muscle of superficial and deep perineal pouches (bulbospongiosus, ischiocavernosus, superficial transverse perinei, deep transverse perinei and sphincter urethrae (Fig. 15.19).
- The dorsal nerve of the penis (clitoris)is the other terminal branch of the pudendal nerve. It passes forwards through the pudendal canal lying above the internal pudendal vessels. At the anterior end of the canal, the nerve enters the deep perineal pouch. The nerve pierces the perineal membrane and runs forwards along the inner surface of ischiopubic ramus. Then the nerve passes through the gap between the arcuate pubic and transverse perineal ligaments to reach the dorsum of penis (clitoris). Here, it lies on the fascia penis (clitoris), lateral to dorsal artery of penis (clitoris). It supplies the skin of the penis, prepuce and glans.

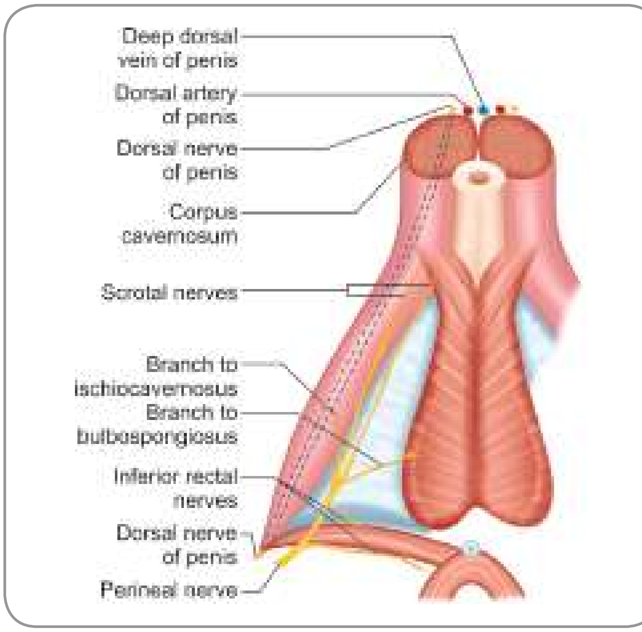


Fig. 15.19: Branches of the perineal nerve as seen in the male perineum

Clinical Correlation

Pudendal nerve block: Indications include—(a) the application of forceps during difficult child birth, (b) operations in the perineum. The ischial spine is palpated through the vagina. The needle is then inserted through the vaginal wall guided by the finger. The pudendal nerve is infiltrated with local anaesthetic where it crosses the ischial spine.

Multiple Choice Questions

1. The structure that continues from the canal of epididymis is:
   a. Ductus deferens
   b. Seminal vesicle
   c. Ejaculatory duct
   d. Prostatic urethra

2. Perineum includes all structures
   a. Of the perineal pouches only
   b. Related to pelvic inlet
   c. Related to pelvic outlet
   d. Related to perineal body

3. The pudendal nerve divides into its terminal branches in the:
   a. Pudendal canal
   b. Ischiorectal fossa
   c. Gluteal region
   d. Pelvis

4. The apex of the ischiorectal fossa is formed by:
   a. Fusion of anal and obturator fasciae
   b. Levator ani muscle
   c. Inferior pad of fat
   d. Sphincter ani externus

5. Deep perineal pouch:
   a. Lies superior to the perineal membrane
   b. Lies superficial to the perineal membrane
   c. Lies at the sides of perineal membrane
   d. Has no relation to the perineal membrane

ANSWERS

1. a **2.** c **3.** a **4.** a **5.** a

Clinical Problem-solving

Case Study 1: A 54-year-old man has an ischiorectal sinus.
- What is the primary cause for such a sinus to occur?
- What are the possible sources of infection?
- Why is any abcess in the ischiorectal fossa clinically important?

Case Study 2: A 68-year-old woman has prolapse of uterus. While taking history, your colleague finds out that she has had several deliveries and most of them were at home and not in the hospital.
- Can you figure out the primary reason for the prolapse of viscera in this patient?
- Which structure is mainly responsible for the anatomical integrity of the perineum?
- What role is played by the levator ani muscle?

(For solutions see Appendix).

Chapter 16

Peritoneum

Frequently Asked Questions

- Discuss the lesser sac in detail with respect to its formation, boundaries and significance. Give a brief account of the aditus to lesser sac.
- Write notes on: (a) Lesser omentum, (b) Transverse mesocolon, (c) Right subhepatic space, (d) Duodenal recesses.
- Give an account of the vertical disposition of peritoneum.
- Write briefly on: (a) Greater omentum, (b) Peritoneal cavity in the female, (c) Extraperitoneal spaces.

The abdominal cavity is lined by a serous membrane called the ***peritoneum***. The viscera which lie within the abdominal cavity are clothed by the peritoneum.

The peritoneum can be defined as a closed sac that is invaginated by the abdominal viscera. It has a ***parietal*** layer that lines the abdominal wall and a ***visceral*** layer that covers and is in intimate relationship to the viscera.

The free surfaces of both the layers are smooth and lined by a layer of flattened mesothelium. The parietal and visceral layers of peritoneum are separated by a potential space called the ***peritoneal cavity***. This space contains a thin film of fluid (peritoneal fluid) that has a lubricating function. The fluid allows free movement of the viscera against the abdominal wall and against each other.

Though defined as a closed sac, which is true in males, the peritoneal cavity forms an open sac in females as the pelvic peritoneum opens into the outside through its communication with the uterine tubes.

It has to be noted that the terms ***abdominal cavity*** and ***peritoneal cavity*** are not one and the same. The abdominal cavity contains all the contents of the abdomen, while the peritoneal cavity is only a potential space. As all the abdominal viscera only invaginate into the peritoneum, the visceral peritoneum is reflected back from the viscera without totally enclosing them. Hence, all viscera are intra-abdominal but extraperitoneal.

The invagination can be complete or partial. Some viscera which are attached to the posterior abdominal wall project only partially into the peritoneal cavity. As a result they are in contact with the posterior abdominal wall, and are only partly covered by peritoneum. Such viscera and other structures are described as being ***retroperitoneal***. A retroperitoneal viscus has very limited mobility. Examples of retroperitoneal viscera are the duodenum, ascending colon, descending colon and the kidneys.

In contrast to such viscera, others are suspended from the abdominal wall (posterior abdominal wall) by double layered folds of peritoneum passing from the abdominal wall to the viscera. The best example of such a viscus is the small intestine. The fold of peritoneum by which it is attached to the posterior abdominal wall is called the ***mesentery***.

PERITONEAL FOLDS

The formation of various peritoneal folds/ligaments is related to the embryological development of the abdominal cavity and the contained viscera. In the embryo, the gut is a straight midline tube attached to the posterior abdominal wall by a ***dorsal mesentery***. To begin with, the attachment of the dorsal mesentery to the body wall is in the midline. However, as the gut increases in length it gets folded on itself and comes to be arranged in a complicated manner. The attachments of the dorsal mesentery corresponding to different parts of the gut also shift along with the position of the parts of the gut. In particular, the stomach and the transverse colon come to lie transversely from their original vertical position and the dorsal mesentery suspending them also is aligned accordingly. Simultaneously some parts of the gut lose their mesenteries and become retroperitoneal.

The various folds of peritoneum are named according to the viscera that they suspend. The prefix mes/meso indicates the derivation of the peritoneum from the mesoderm of the embryo.

The fold of peritoneum that suspends the greater part of the small intestine is called the ***mesentery*** (mes+enteron);

The fold of peritoneum suspending the transverse colon is called the ***transverse mesocolon*** (mes+colon), and that suspending the sigmoid colon is called the ***sigmoid mesocolon.***

DEVELOPMENTAL CHANGES ALTERING THE PERITONEUM

However, the arrangement is not as simple in the cranial part of the gut including the abdominal part of the oesophagus, the stomach, and the first two centimeters of the duodenum as elsewhere. The cranial part of the gut (the future stomach) is attached to the abdominal wall by two embryonic folds of peritoneum (Figs 16.1 and 16.2). One of these, the ***dorsal mesogastrium,*** is merely the cranial part of the dorsal mesentery discussed above. The second fold, the ***ventral mesogastrium*** passes from this part of the gut to the anterior abdominal wall.

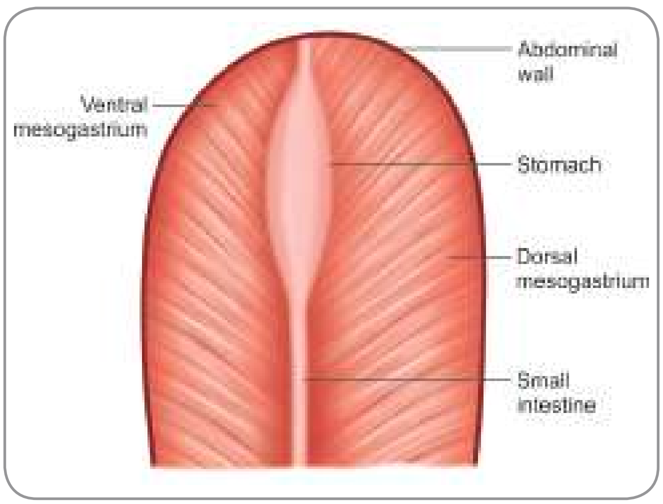


Fig. 16.1: Scheme to show the ventral and dorsal mesogastria

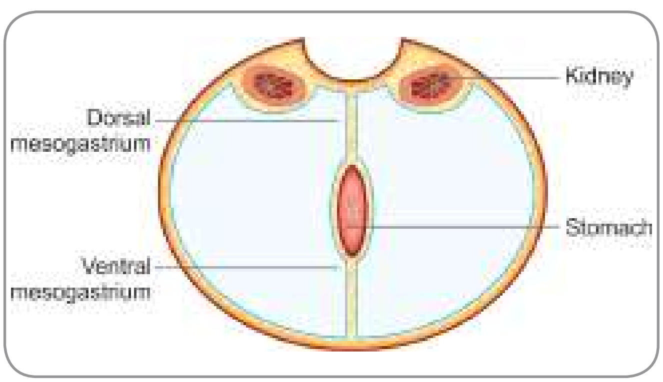


Fig. 16.2: Scheme to show the orientation of the dorsal and ventral mesogastria before rotation of the stomach

Ventral Mesogastrium

In later development, the ***liver*** develops within the ventral mesogastrium so that the peritoneum forming it becomes divided into ***three parts***.

1. The first part passes from the stomach to the liver. This is the ***lesser omentum*** (Fig. 16.3).
2. The second part surrounds the liver forming the visceral peritoneum over it.
3. The third part passes from the liver to the anterior abdominal wall and diaphragm in the form of ***falciform ligament***, ***superior and inferior layers of coronary ligaments*** and ***right and left triangular ligaments*** (Fig. 16.4) (These ligaments are merely folds of peritoneum and have no similarity to ligaments of joints).

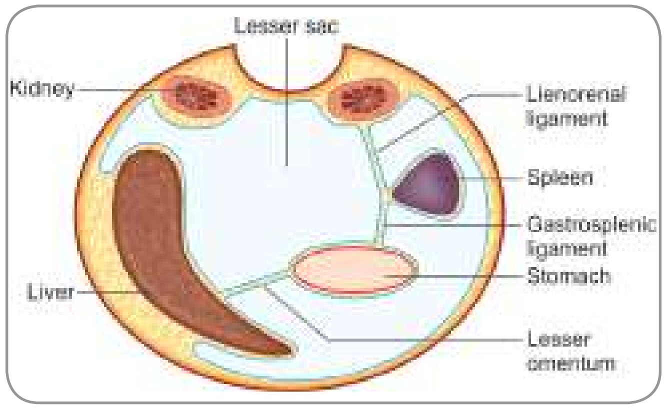


Fig. 16.3: Scheme to show the alteration of the ventral and dorsal mesogastria as a result of the formation of the liver and spleen

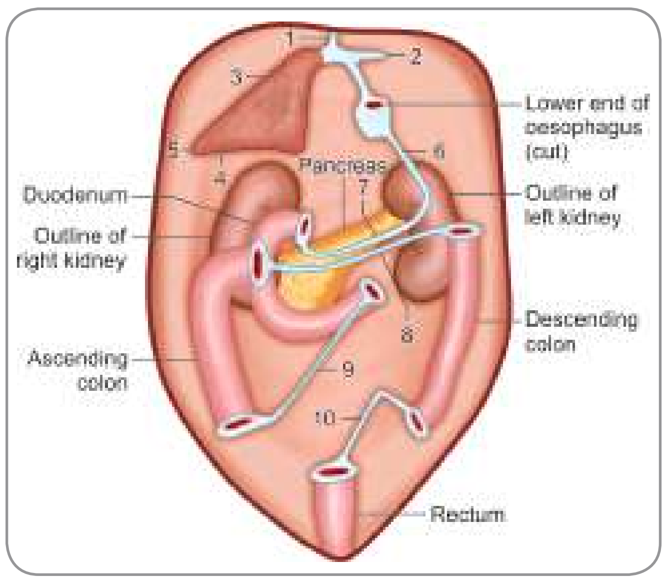


Fig. 16.4: Scheme to show the retroperitoneal parts of the gut, and the attachments of folds to the posterior wall of the abdomen

Key: 1. Falciform ligament **2.** Left ligament **3.** and **4.** Superior and inferior layers of coronary ligament **5.** Right triangular ligament **6.** Lienorenal ligament **7.** Greater omentum **8.** Transverse mesocolon **9.** Mesentery of jejunum and ileum **10.** Pelvic mesocolon

Dorsal Mesogastrium

The arrangement of the dorsal mesogastrium also becomes altered due to further development. The ***spleen*** develops within the cranial part of the dorsal mesogastrium thus dividing it into:

- A part passing from the stomach to the spleen, called the ***gastrosplenic ligament*** and
- A part passing from the spleen to the posterior abdominal wall. The attachment of this part of the dorsal mesogastrium shifts from the midline to the left side, over the region of the left kidney. As a result, the part of the dorsal mesogastrium passing from the spleen to the posterior abdominal wall becomes the ***lienorenal ligament*** (spleen to kidney; Latin.lien=spleen) (also see Figure 16.4).

At this time of development, the orientation of the stomach changes from vertical to transverse position. Hence, the attachment of the dorsal mesogastrium to the posterior abdominal wall caudal to the gastrosplenic and lienorenal ligaments also changes from a vertical position to a transverse one. Along with the change in position,the dorsal mesogastrium also elongates greatly and forms a double layered loop of peritoneum that runs downwards from the stomach, curves on itself, and runs up again to reach the attachment on the posterior abdominal wall. This double-layered fold of peritoneum is called the ***greater omentum*** (Fig. 16.5).

Figure 16.4 shows the final position of the attachment of the dorsal mesentery on the posterior abdominal wall. In those parts where the gut has become retroperitoneal, the gut itself is seen. Between these segments of gut there are the attachments of the remnants of the dorsal mesentery.

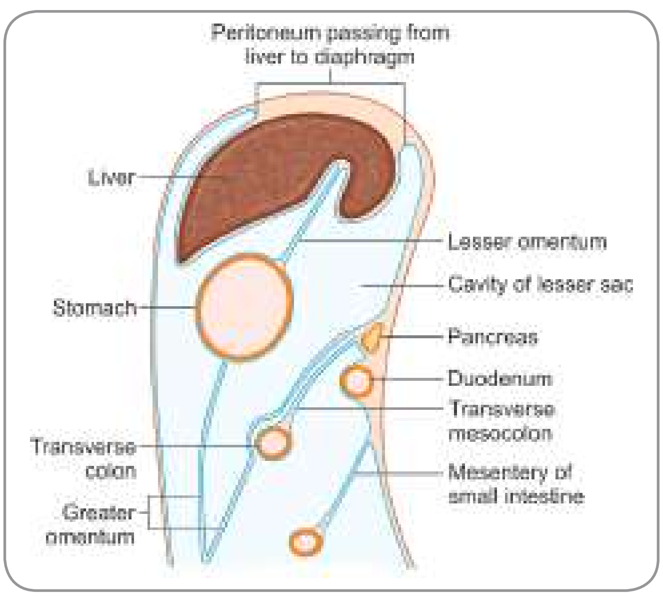


Fig. 16.5: Schematic sagittal section through the abdomen to show some features of peritoneum

PERITONEAL CAVITY

The peritoneal cavity is divided into two major regions, one called the ***greater sac*** (Cavum Peritonei) and a second region called the ***lesser sac***. The lesser sac (also called the ***omental bursa*** or the omental sac) is actually a diverticulum from the greater sac and lies behind the stomach and the adjoining structures (Figs 16.4 and 16.5).

The greater and lesser sacs communicate through a narrow opening that lies just above the duodenum. This opening is the ***aditus to the lesser sac*** (or ***foramen epiploicum*** or ***epiploic foramen*** or ***foramen of Winslow***). Though various folds of peritoneum are described, it should be understood that the peritoneum is a continuous membrane which lines the parietal wall (where it is called the ***parietal peritoneum***), and also covers the contained viscera (where it is called the ***visceral peritoneum***). As the membrane is reflected from the parietal to the visceral layer, it may be raised into folds.

PERITONEAL DISPOSITION

Though the peritoneum started as a simple lining in the embryo, it undergoes several modifications and alterations due to various developmental processes. The final outcome is a complicated arrangement. The arrangement can be divided into the vertical and horizontal dispositions of the peritoneum.

Vertical Disposition of the Peritoneum

The tracing of the arrangement of the greater sac in the vertical plane is started from the anterior abdominal wall at the level of umbilicus. Above the level of umbilicus, the parietal peritoneum lining the anterior abdominal wall forms, close to the midline, a sickle shaped bilaminar fold, the falciform ligament. The falciform ligament extends upwards and backwards slightly to the right side and becomes continuous with the visceral peritoneum over the anterosuperior surface of the liver. The falciform ligament presents a posteroinferior free margin which extends from the umbilicus to a notch on the inferior border of the liver. The free margin contains the ***ligamentum teres hepatis*** (obliterated left umbilical vein) and the ***para umbilical vein*** which is a tributary of the left branch of portal vein. Traced above, the falciform ligament diverges at the superior surface of liver into the right and left layers. The right layer continues as the superior layer of coronary ligament and the left layer as the left triangular ligament.

The ***superior layer of the coronary ligament*** is that part of the parietal peritoneum reflected from the diaphragm to the superior surface of the liver. It then continues as the visceral peritoneum which covers the anterior surface of the liver, inferior border and the inferior surface of the right lobe of the liver.

On the right side of the gall bladder, the peritoneum is reflected to the upper part of right kidney and a part of right supra renal gland as the inferior layer of coronary ligament.

Traced below, the inferior layer of coronary ligament covers the anterior surface of the right kidney, second part of duodenum and the right colic flexure and forms the hepatorenal pouch. Thereafter, it covers the front and sides of the ascending colon and caecum and becomes continuous with the peritoneum of the pelvic cavity.

Traced to the right, the inferior and the superior layers of coronary ligament gradually approach each other on the right margin of the liver and ultimately fuse with each other to form the right triangular ligament which connects the right lobe of the liver to the diaphragm. The right triangular ligament forms the apex of the triangular bare area of the liver with the groove for IVC forming the base of the area and the superior and inferior layers of coronary ligament forming the sides.

Traced to the left, the visceral peritoneum covers the inferior surface and sides of the gall bladder, inferior surface of the quadrate lobe of the liver up to the anterior margin of the porta hepatis and the inferior surface of the left lobe including the left lip and left wall of the fissure for the ligamentum venosum. From the posterior border of the left lobe, it is reflected to the diaphragm as the posterior layer of left triangular ligament. The left triangular ligament is that part of parietal peritoneum reflected from the diaphragm to the left lobe of the liver and has an anterior layer, free margin and a posterior layer. The anterior layer of the left triangular ligament is continuous with the left layer of falciform ligament.

The peritoneum at the anterior margin of the porta hepatis and the bottom of the fissure for ligamentum venosum, becomes continuous with the anterior layer of lesser omentum and from the posterior margin of the porta hepatis becomes continuous with the posterior layer of lesser omentum. The lesser omentum extends between the liver (above) and the stomach and proximal part of duodenum (below). The part of the lesser omentum between the liver and the lesser curvature of stomach is called the ***hepatogastric ligament*** and the part between the liver and the duodenum is called the ***hepatoduodenal ligament***. The hepatoduodenal part is thickened at its right free margin (also called the right free margin of lesser omentum) and contains the hepatic artery, bile duct and portal vein and forms the anterior boundary of the epiploic foramen.

The anterior and the posterior layers of lesser omentum diverge at the lesser curvature and sweep downwards to cover the anterosuperior and posteroinferior surfaces of the stomach respectively. On reaching the greater curvature of the stomach and the proximal 2 cm of the duodenum, the two layers reunite and form the greater omentum. In contrast to the other folds of peritoneum, the greater omentum contains four layers. The layer covering the anterosuperior surface of stomach, on reaching the greater curvature, hangs down to form the ***first*** (anterior most) ***layer of the greater omentum***; the layer covering the posteroinferior surface of stomach, on reaching the greater curvature, similarly hangs down to form the ***second layer of greater omentum***. The two layers descend downwards for some distance and then fold backwards to ascend as the ***third and fourth layers of greater omentum***. So, the anteriormost layer folds to form the fourth layer, i.e., the posteriormost layer; the second layer forms the third layer. The space between the second and third layers of greater omentum forms part of the lesser sac.

The posteriormost layer of greater omentum runs up to reach the posterior abdominal wall; it covers the anterior surface of the head and the anterior border of the body of pancreas. It is reflected from the pancreas to the transverse colon, covers the latter and then reflected back to the pancreas. The layer running from the pancreas to the transverse colon forms the superior layer of transverse mesocolon and the layer that goes back to pancreas is the inferior layer of transverse mesocolon. The inferior layer of transverse mesocolon which has reached the pancreas, subsequently gets reflected over the anterior surfaces of the horizontal and ascending parts of the duodenum to reach the posterior abdominal wall.

From the posterior abdominal wall, the peritoneum reaches the jejunum and ileum as the right layer of mesentery, invests them and returns to the posterior abdominal wall as the left layer of mesentery. It then descends over the posterior wall structures like the abdominal aorta, IVC, ureter and psoas major and descends into the pelvic cavity. In the pelvic cavity, it is reflected from the posterior pelvic wall as the anterior layer of sigmoid mesocolon, invests the sigmoid colon, returns as the posterior layer of sigmoid mesocolon. It then descends, covering the front and sides of the upper third and the front of the middle third of rectum.

Further tracing of the vertical disposition differs between the males and females.

In males, the peritoneum is reflected from the front of middle third of rectum to the upper ends of seminal vesicles and upper surface of the urinary bladder. Between the rectum and the urinary bladder, the peritoneum dips slightly downwards forming a recess called the ***rectovesical pouch***.

In females, the peritoneum is reflected from the front of the middle third of rectum to the posterior fornix of the vagina and thence to the posterior surface of the cervix and body of uterus forming the rectouterine fold. The fold dips downwards forming a recess called the rectouterine pouch. The peritoneum continues over the fundus of the uterus and descends on its anterior surface up to the junction of the cervix and body of uterus and is reflected forwards from there to the upper surface of the bladder forming a shallow vesicouterine pouch. From the lateral walls of the uterus, the peritoneum is reflected to the lateral pelvic wall as the broad ligament.

From the apex of the bladder, the peritoneum continues as the median and medial umbilical ligaments to the anterior abdominal wall up to the level of the umbilicus. With this the vertical disposition of the peritoneum is traced back to the starting point, namely the umbilicus.

Horizontal Disposition of Peritoneum

The horizontal disposition of the peritoneum can be traced in three subdivisions:

1. In lesser pelvis;
2. In lower abdomen—below the level of transverse colon;
3. In upper abdomen—above the level of transverse colon.

Lesser Pelvis

It was already seen that the peritoneum lining the posterior abdominal wall enters the pelvic cavity as sigmoid mesocolon and then is reflected forwards from the middle third of rectum to the urinary bladder in males. From the sides of the upper third of rectum, the peritoneum is reflected to the lateral pelvic wall forming the ***pararectal fossae*** in both sexes. In the males, each pararectal fossa is bounded laterally by the ipsilateral ***sacrogenital fold***; and in the females by the ***rectouterine fold*** (Fig. 16.6).

On either side of the urinary bladder, the peritoneum is reflected to the lateral pelvic wall to form the ***paravesical fossae*** (Fig. 16.7). Each paravesical fossa is bounded laterally by a ridge raised by the ***ductus deferens*** (in the males) or by the ***round ligament of uterus*** (in the females).

In females, on either side of the uterus the peritoneum is reflected laterally to form the ***broad ligament.***

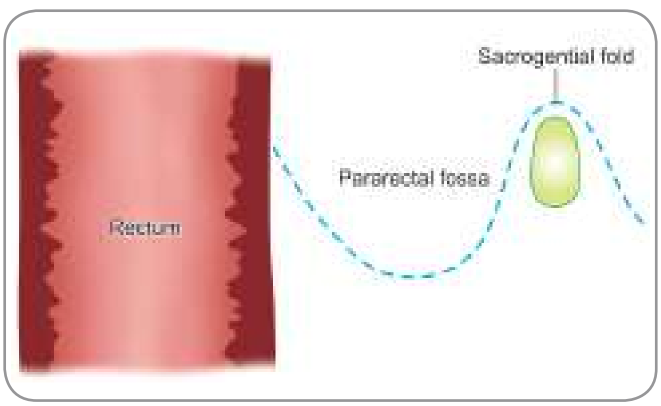


Fig. 16.6: Schematic coronal section through the rectum to show the pararectal fossa

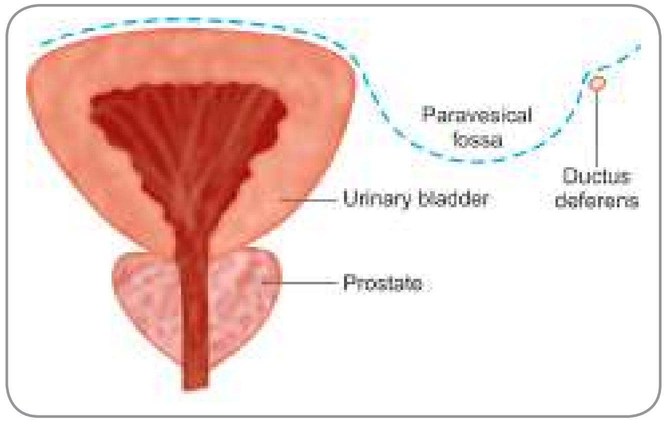


Fig. 16.7: Schematic coronal section through the urinary bladder to show the paravesical fossa

Lower Abdomen

The peritoneum lining the lower part of anterior abdominal wall is raised to form five short vertical folds which converge as they pass upwards (Fig. 16.8).

1. In the midline, the ***median umbilical fold*** is present which is formed by the median umbilical ligament (remnant of urachus).
2. Further laterally, right and left ***medial umbilical folds*** produced by the obliterated umbilical arteries and ***lateral umbilical folds*** produced by the right and left inferior epigastric arteries are present.
3. On either side of the median umbilical fold (i.e., between the median and medial folds) depressions called the (right and left) ***supravesical fossae*** are seen.
4. Between the medial and lateral umbilical folds, depressions called the ***medial inguinal fossae*** are seen.

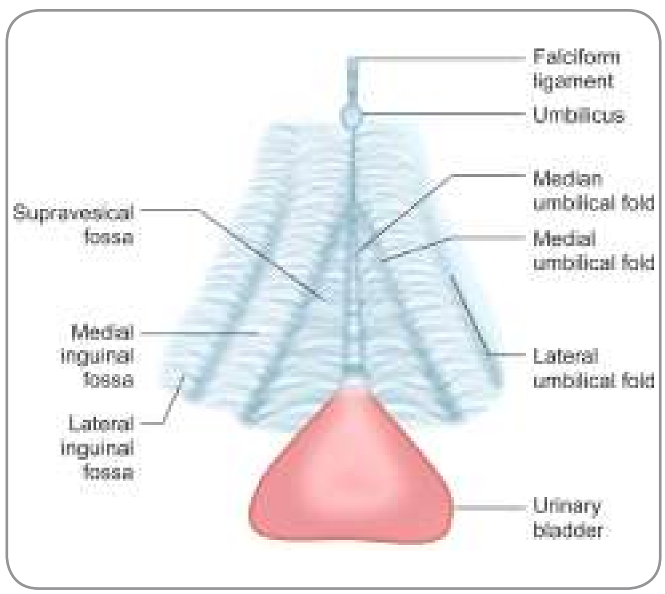


Fig. 16.8: Peritoneal folds on posterior aspect of anterior abdominal wall

- Lateral to the lateral folds are the depressions called the ***lateral inguinal fossae***. The deep inguinal rings are related to these fossae.

Further tracing of the peritoneum below the level of transverse colon is as follows:

Traced from the linea alba in the median plane and followed in a horizontal direction to the right, the peritoneum lines the inner surface of the anterior abdominal wall and further laterally, the lateral abdominal wall up to the lateral border of quadratus lumborum. From here, it is reflected over the front and sides of the ascending colon and encloses the caecum and appendix. The peritoneum then can be ***traced over the duodenum***, psoas major and inferior venacava towards the median plane in the posterior abdominal wall and becomes continuous with the right layer of mesentery over the superior mesenteric vessels. After investing the small intestine, it turns back as the left layer of mesentery. The left layer of mesentery is continuous with the peritoneum covering the left psoas major in its horizontal disposition and then is reflected over the front and sides of the descending colon and then lines the antero lateral abdominal wall to return to the median plane again.

Upper Abdomen

Above the level of transverse colon, the peritoneum of the greater sac is complexly arranged.

It is already seen that from the midline of the supra umbilical part of the anterior abdominal wall, the parietal peritoneum is reflected backward and somewhat to the right as the bilaminar fold called the ***falciform ligament***. Its vertical tracing is already dealt with. Now to trace horizontally to the right, the right layer of falciform ligament continues as the lining of the inner surface of the anterolateral abdominal wall; it then covers the anterior surface of the right kidney and part of the right supra renal gland and is continuous with the peritoneum in front of inferior vena cava which forms the ***posterior boundary of the epiploic foramen.***

Traced to the left, the left layer of falciform ligament, after lining the anterolateral abdominal wall covers the anterior surface of the upper part of the left kidney, thence is reflected to the posterior lip of the hilum of the spleen as the ***posterior layer of lienorenal ligament***. The peritoneum then extends forwards to invest the spleen and is reflected from the anterior lip of the hilum of the spleen to the fundus of the stomach as the ***anterior layer of gastrosplenic ligament***. From the fundus of the stomach, the peritoneum further continues to cover the anterosuperior surface of the stomach and at the lesser curvature continues as the ***anterior layer of lesser omentum***. The anterior layer of lesser omentum presents a right free margin around the portal vein, bile duct and hepatic artery which forms the ***anterior boundary of the epiploic foramen***. At this border, the anterior layer of lesser omentum (formed by the peritoneum of the greater sac) becomes continuous with the posterior layer of lesser omentum (formed by the peritoneum of the lesser sac). It is pertinent to mention here that the posterior layer of lesser omentum which forms the second and third layers of greater omentum and walls of the lesser sac forms the ***anterior layer of lienorenal ligament*** and the ***posterior layer of gastrosplenic ligament***.

Epiploic Foramen

Immediately posterior to the right free margin of the lesser omentum the ***aditus to the lesser sac/epiploic foramen*** is seen. Its boundaries are as follows:

- ***Anteriorly***, right free margin of lesser omentum.
- ***Posteriorly***, peritoneum over inferior vena cava.
- ***Below***, superior part of duodenum.
- ***Above***, caudate process of the liver.

Omenta

The omenta (Latin.Oment=membrane enclosing the bowel) are folds of peritoneum connected to the stomach. Two of them are customarily described, namely the lesser and the greater omenta, though other folds of peritoneum may be called omenta with the prefix of an embellished description.

Lesser Omentum

Other names: Omentum minus, gastrohepatic omentum, hepatogastric and hepatoduodenal ligaments**.**

The lesser omentum is a fold of peritoneum which extends to the liver from the lesser curvature of the stomach and the commencement of duodenum.

Attachments

The lesser omentum is continuous with the two layers of visceral peritoneum which cover the anterosuperior and posteroinferior surfaces of the stomach and the first 2 cm of duodenum.

From the lower part of the lesser curvature of stomach and the upper border of duodenum, the two layers ascend straight up as a double fold to the ***porta hepatis***; and from the upper part of lesser curvature, the layers ascend superomedially to the right and attach to the bottom of the ***fissure for ligamentum venosum***. The hepatic attachment of lesser omentum is therefore inverted L shaped, with the horizontal limb corresponding to the attachment at porta hepatis and the vertical limb to that of the floor of the fissure for ligamentum venosum (it may be remembered that the lesser curve of stomach conforms to and complements this shape; it is a reversed L).

At the upper end of the fissure for ligamentum venosum, the lesser omentum reaches the diaphragm, where the two layers separate to enclose the abdominal part of oesophagus.

At the right border of the lesser omentum, the anterior and posterior layers are continuous and form a free margin which constitutes the anterior boundary of the epiploic foramen.

Parts of Lesser Omentum

The portion of the lesser omentum extending between the liver and stomach is called the ***hepatogastric ligament*** and that part between the liver and the duodenum the ***hepatoduodenal ligament.***

Contents

At the right free margin, the two layers of lesser omentum enclose the:

- Portal vein;
- Hepatic artery;
- Bile duct;
- Few lymph nodes and vessels;
- Hepatic plexus of nerves.

Close to the lesser curvature of stomach, between its two layers, it encloses the:

- Right and left gastric vessels;
- Gastric nerves;
- Gastric lymph nodes.

Greater Omentum

Other names: Omentum majus, gastrocolic omentum, epiploon.

The greater omentum is the largest peritoneal fold. It consists of a double sheet, folded on itself so that it is made of 4 layers. The anterior and the posterior layers of lesser omentum diverge at the lesser curvature and sweep downwards to cover the anterosuperior and posteroinferior surfaces of the stomach respectively. On reaching the greater curvature of the stomach and the proximal 2 cm of the duodenum, the two layers reunite and form the greater omentum. The layer covering the anterosuperior surface of stomach, on reaching the greater curvature, hangs down to form the ***first*** (anterior most) ***layer of the greater omentum***; the layer covering the posteroinferior surface of stomach, on reaching the greater curvature, similarly hangs down to form the ***second layer of greater omentum***. The two layers descend downwards for some distance and then fold backwards to ascend as the ***third and fourth layers of greater omentum***. So, the anteriormost layer folds to form the fourth layer, i.e., the posteriormost layer; the second layer forms the third layer. The space between the second and third layers of greater omentum forms part of the lesser sac.

The left border of the greater omentum is continuous above with the ***gastrosplenic ligament*** and its right border extends up to the commencement of the duodenum. It should be noted that the gastrosplenic ligament and greater omentum are not merely continuous but the same structure, separated only for descriptive convenience.

Contents

- Adipose tissue of variable amount depending on the nutritional status of the individual.
- Anastomoses of the right and left gastroepiploic vessels between the anterior two layers close to the greater curvature.
- Numerous fixed macrophages, which can be mobilised as necessary. Accumulation of these macrophages as dense patches gives the appearance of ***milky spots*** in the omentum.

Functions

- It is a storehouse of fat.
- Assists in combating infection due to the presence of large number of macrophages which can be mobilised during infection.
- It also helps in limiting the spread of infection in the peritoneal cavity. It moves to the site of infection and becomes adherent to the affected structure thereby sealing it off from the surrounding areas. It is for this reason that the greater omentum is fancily described the ***policeman of the abdomen***.

PERITONEAL CAVITY

As already explained, the peritoneal cavity does not remain a single cavity as in the case of other serous cavities, but is modified and subdivided. Two major parts can be described, namely the ***greater sac*** and the ***lesser sac***. For the sake of easier understanding, the lesser sac is first discussed here.

Lesser Sac (Omental Bursa)

The lesser sac is a fairly large potential recess of the peritoneal cavity that communicates with the main peritoneal cavity (or greater sac) through the ***foramen epiploicum***. It is irregular in shape and is situated behind the stomach and extends beyond its limits. The name ***omental bursa*** is due to the concept that it forms a bursa facilitating the movement of stomach and the name ***lesser sac*** because it forms a smaller portion of the bigger cavity.

Boundaries of Lesser Sac

The sac has anterior and posterior walls which are limited by right, left, upper and lower borders.

Anterior Wall

From above downwards, the anterior wall is formed by:

- The peritoneum covering the caudate lobe and caudate process of the liver,
- Posterior layer of lesser omentum,
- Peritoneum lining the posterior surface of stomach and the adjoining proximal part of duodenum and
- The second layer of greater omentum (posterior of the anterior two layers of greater omentum).

Posterior Wall

From below upwards, the posterior wall is formed by:

- The third layer of greater omentum (anterior of the posterior two layers of greater omentum),
- Peritoneum covering the ***retroperitoneal structures*** namely, anterior surface of upper part of the head, neck and body of pancreas, part of the left kidney and left suprarenal gland, upper part of abdominal aorta, diaphragm and the coeliac trunk with its branches.

Upper Border

The ***upper border*** of the lesser sac is formed as follows:

- Towards the right side it is formed by the reflection of peritoneum from the upper end of the posterior surface of the caudate lobe of the liver to the diaphragm.
- To the left of the caudate lobe it is formed by reflection of peritoneum from the back of the upper part of the fundus of the stomach to the diaphragm; this peritoneum forms the ***gastrophrenic ligament*** (Fig. 16.9).

Lower Border

The lower border of the lesser sac is formed by the line of reflection of the anterior two layers of the greater omentum as the posterior two layers.

Left Border

- The ***left border*** of the lesser sac is formed, in the greater part of its extent, in the same way as the lower border i.e., by continuity of the anterior two layers of the greater omentum with its posterior two layers.
- Higher up, the left border is formed by the gastrosplenic and lienorenal ligaments (Fig. 16.10). These ligaments are continuous, below, with the greater omentum; and above with the gastrophrenic ligament.

Right Border

The formation of the right border of the lesser sac can be divided into several parts as follows:

- The lower part of the right border (below the transverse colon) is formed by continuity of the anterior two layers with the posterior two layers of the greater omentum.
- At the upper end of the greater omentum, its anterior two layers pass on to the anterior and posterior aspects of the stomach and the proximal portion of the superior part of the duodenum. The peritoneum on the back of this part of the duodenum gets reflected on to the front of the neck of pancreas thus forming the right margin of the lesser sac at this level.
- Immediately above the duodenum there is a gap in the right border of the sac because of the presence of the foramen epiploicum (Fig. 16.10).
- Above the foramen epiploicum, the caudate lobe of the liver projects into the lesser sac from the right side. Here the right margin of the lesser sac is formed by the reflection of the peritoneum from the diaphragm to the right margin of the caudate lobe.

Interior of the Lesser Sac

The lesser sac is encroached upon by two sickle shaped peritoneal folds known as the ***superior (left)*** and ***inferior***

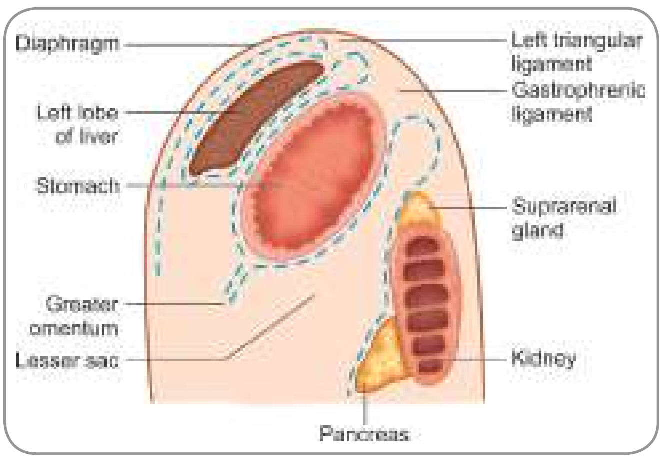


Fig. 16.9: Schematic sagittal section of the upper part of the abdomen to the left of the caudate lobe of the liver, but to the right of the spleen

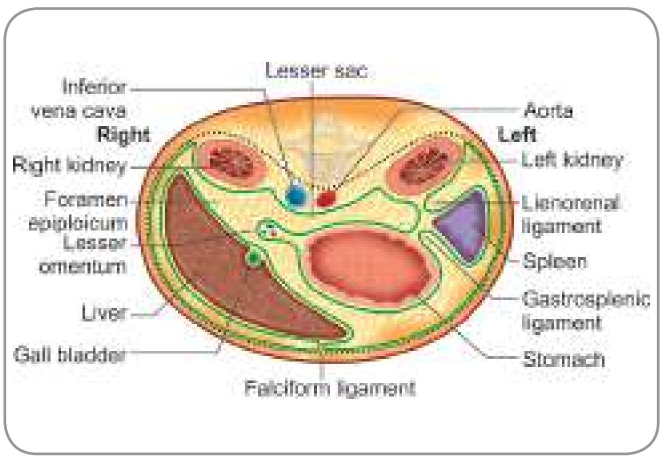


Fig. 16.10: Transverse section across abdomen at the level of the foramen epiploicum to show peritoneal reflections

(right) gastropancreatic folds which are drawn into the sac by the left gastric and hepatic arteries respectively.

The ***left gastropancreatic fold*** is formed by the ***left gastric artery*** as it passes from the posterior abdominal wall to the lesser curvature of stomach. The ***right gastropancreatic fold*** (inferior) is formed by the ***hepatic artery*** as it passes forwards from the posterior abdominal wall to the lesser omentum.

The two folds approximate closely leaving an aperture called the ***foramen bursae omentalis majoris***. This foramen divides the omental bursa into a ***superior recess*** above and an ***inferior recess*** below. The superior recess thus lies behind the liver and lesser omentum and the inferior recess lies behind the stomach and within the greater omentum.

GREATER SAC

The part of the peritoneal cavity other than the lesser sac forms the greater sac. It is large and covers almost the entire abdominal cavity

It is subdivided into an anterosuperior ***supracolic compartment*** and a posteroinferior ***infracolic compartment*** by the transverse colon and the transverse mesocolon which are virtually placed as a transverse partition near the middle of the cavity.

Supracolic Compartment

The supracolic compartment are present mainly under cover of the costal margin and diaphragm. It contains the liver, stomach, spleen and the superior part of duodenum and lies anterior to the pancreas, duodenum, kidney and supra renal glands. The attachments of the liver to the anterior abdominal wall and the diaphragm subdivide the supracolic compartment into six spaces. As all these spaces lie under the diaphragm, they are also called the ***sub-phrenic spaces.*** Of the six recesses, four are intra peritoneal and two are extra peritoneal. The recesses are also sub classified as ***supra hepatic*** and ***sub hepatic spaces*** in relation to their position with regard to the liver.

The six subphrenic recesses are:

1. Right anterior intraperitoneal recess
2. Right posterior intraperitoneal recess
3. Right extraperitoneal space
4. Left anterior intraperitoneal recess
5. Left posterior intraperitoneal recess
6. Left extraperitoneal space

Right Anterior Intraperitoneal Recess

The right anterior intra-peritoneal recess lies on the right side of the falciform ligament. As it lies anterosuperior to the liver, it is also called the ***right supra hepatic space***. Its boundaries are:

- ***Anteriorly:*** Anterior abdominal wall and diaphragm;
- ***Posteriorly:*** Superior and anterior surfaces of the right lobe of liver;
- ***Above:*** Superior layer of coronary ligament and
- ***Below:*** Communicates with the right posterior intraperitoneal recess around the inferior border of the liver.

Right Posterior Intraperitoneal Recess

The right posterior intraperitoneal recess is the most dependent part of the abdominal peritoneal cavity in the supine position. As it lies below the liver, it is also called the ***right sub hepatic space***. As it is related to the liver on its anterior aspect and to the right kidney on its posterior aspect, it is described as the ***hepatorenal pouch*** and named after the **19th century** British surgeon as the ***pouch of Morison.*** Its boundaries are:

- ***Anteriorly:*** Inferior surface of the right lobe of liver;
- ***Posteriorly:*** Anterior surface of right kidney, a part of right supra renal gland and right colic flexure;
- ***Above:*** Inferior layer of coronary ligament;
- ***Below:*** Communicates with the infracolic compartment of the greater sac along the external right paracolic gutter and thence opens into the pelvic peritoneum;
- ***Left side:*** Communicates with the omental bursa through the epiploic foramen and
- ***Right side:*** Limited by the diaphragm and communicates with the right anterior intraperitoneal recess around the free margin of the right triangular ligament.

Right Extraperitoneal Space

This is space in relation to and coextensive with the bare area of the liver. It lies as a narrow space between the liver and the diaphragm. Its boundaries are:

- ***Above:*** Superior layer of coronary ligament;
- ***Below:*** Inferior layer of coronary ligament;
- ***Right side:*** Right triangular ligament and
- ***Left side:*** Inferior vena cava.

Left Anterior Intraperitoneal Recess

The left anterior intraperitoneal recess lies on the left side of the falciform ligament. As it lies anterosuperior to the liver it is also called the ***left supra hepatic space***. Its boundaries are:

- ***Anteriorly:*** Anterior abdominal wall;
- ***Posteriorly:*** Left triangular ligament, left lobe of the liver, stomach, spleen;
- ***Above:*** Diaphragm and
- ***Below:*** Communicates with the rest of the supracolic compartment.

Left Posterior Intraperitoneal Recess

The left posterior intra peritoneal recess is also called the ***left sub hepatic space***. It is the ***omental bursa*** or ***lesser***

sac. The boundaries of lesser sac are already discussed. It is closed on all sides except at its upper right margin where it communicates with the greater sac (the hepatorenal pouch of Morison portion of the greater sac to be very precise) through the epiploic foramen.

Left Extraperitoneal Space

This is the narrow space between the stomach and the diaphragm. A small portion of the posterior surface of the fundus of stomach is not covered by peritoneum. This is the place where the two layers of the gastrophrenic ligament diverge from each other. Since this area has no peritoneum, it is called the ***bare area of the stomach***. The left extra-peritoneal space lies between this bare area and the diaphragm with which the bare area is in contact. The boundaries of the left extra peritoneal space are:

- ***Anteriorly:*** Bare area of stomach and
- ***Posteriorly:*** Diaphragm, left supra renal gland and upper part of left kidney.

Infracolic Compartment

The infracolic compartment contains the ascending, transverse and descending colons and is also filled with coils of jejunum and ileum. It is divided into the right and left infracolic spaces by the root of the mesentery of small intestine.

Right Infracolic Space

It is a triangular space with its apex directed downwards. The right and left walls of the triangular space come close together at the apex thereby closing the space from the pelvic cavity below. Hence infection from this space rarely affects the pelvis. Its boundaries are:

- ***Above:*** Root of transverse mesocolon;
- ***Right side (right wall):*** Ascending colon and
- ***Left side (left wall):*** Root of mesentery.

Left Infracolic Space

The boundaries of the left infracolic space are similar to that of the right side except that it freely communicates with the pelvic cavity below as the root of mesentery and the descending colon (the two structures which form the sides of the space) are placed well away from each other. This space is more or less quadrangular in shape. The boundaries are:

- ***Above:*** Root of transverse mesocolon;
- ***Right side:*** Root of mesentery and
- ***Left side:*** Descending colon.

Intraperitoneal Fossae

Apart from the major supra colic and infra colic compartments, a number of small recesses are present in the peritoneal cavity. These small spaces are bound by various peritoneal folds found within the peritoneal cavity. These fossae or recesses are significant because loops of bowel can get incarcerated and strangulated within these fossae. As the entrance to such a recess must be cut to relieve the strangulation, it is important to know the vascularity of the folds guarding these recesses.

The recesses are broadly classified as follows:

- Duodenal recesses
- Caecal recesses
- Intersigmoid recess

The omental bursa is also sometimes considered as one of the intraperitoneal recesses.

Duodenal Recesses

The duodenal recesses are:

- The ***superior duodenal recess*** lies to the left of the upper part of the ascending part of the duodenum. It is caused by a fold of peritoneum running from the duodenojejunal flexure to the posterior abdominal wall. This fold is the duodenojejunal fold or the superior duodenal fold. The recess is open downwards and is closely related to the inferior mesenteric and left renal veins (which lie behind the left edge of the peritoneal fold), and to the abdominal aorta.
- The ***inferior duodenal recess*** lies a little below the superior recess. It opens upwards. It is formed due to the presence of the inferior duodenal fold or the duodenomesocolic fold. This fold extends from the fourth part of duodenum to the transverse mesocolon. The fold has a sharp margin that increases the risk and is in intimate relation to the left colic artery and the inferior mesenteric vein.
- The ***paraduodenal recess*** lies a little to the left of and behind the ascending part of the duodenum in conjunction with the superior and inferior duodenal recesses. A paraduodenal fold of peritoneum that lifts up from the left with a right free edge predisposes to this recess. This fold contains the inferior mesenteric vein and the ascending branch of the left colic artery. The fold and the recess are seen in the newborn and young infants and not usually in the adults.
- The ***retroduodenal recess,*** the largest of the duodenal recesses**,** lies behind the horizontal and ascending parts of the duodenum, in front of the abdominal aorta. Its opening is directed downwards and to the left. It lies between the superolateral and inferomedial duodenoparietal folds of peritoneum. Though largest, it is also the rarest.
- The ***duodenojejunal recess*** lies to the left of the abdominal aorta deep to the transverse mesocolon. The pancreas, the left kidney and the left renal vein are closely

related to it. Otherwise called the ***mesocolic recess***, it is frequently seen. It lies between two folds of periotoneum which run from the duodenojejunal junction to the posterior aspect of the transverse mesocolon.

- The ***mesentericoparietal recess*** lies below the duodenum, behind the upper part of the mesentery. The superior mesenteric artery lies in the anterior wall of its opening. The recess itself is produced by a fold of mesentery raised by the superior mesenteric artery.

Caecal Recesses

- The ***superior ileocaecal recess*** lies to the left of the ileocaecal junction in front of the terminal ileum. It is bounded anteriorly by a fold of peritoneum (called the ***vascular fold of caecum***) containing the anterior caecal vessels. The recess opens downwards and to the left and is often seen in children but not in adults.
- The ***inferior ileocaecal recess*** lies to the left of the caecum in front of the mesoappendix and behind the terminal part of the ileum. It is bounded in front by a fold passing from the ileum to the mesoappendix called the ***ileocaecal fold***. Though the ileocaecal fold is customarily called the ***bloodless fold of Treve***, it sometimes may contain blood vessels. The recess opens downwards and to the left.
- The ***retrocaecal recess*** lies behind the caecum. The vermiform appendix usually lies in this recess. It is produced by two folds of peritoneum called the ***parietocolic folds*** which pass from the caecum to the posterior abdominal wall.
- A recess may also be present deep to the apex of the sigmoid mesocolon. It is related to the left ureter and the left common iliac artery.

Intersigmoid Recess

It lies behind the apex of the inverted V shaped parietal attachment of the root of the sigmoid mesocolon. It is funnel shaped with the orifice opening downwards. The posterior wall of the recess formed by the peritoneum of the posterior abdominal wall covers the left ureter as it crosses the bifurcation of the common iliac artery while entering the pelvic cavity. It is produced by a small fold of peritoneum that occurs between the mesocolon and the parietal peritoneum most likely due to an improper blending of the two.

SPECIAL FOLDS OF PERITONEUM

Folds of peritoneum which suspend parts of the digestive tract deserve special attention.

Transverse Mesocolon

The mesentery of the transverse colon (called the ***transverse mesocolon***) is a broad fold of visceral peritoneum reflected anteriorly from the posterior abdominal wall. It suspends the transverse colon. The root of the transverse mesocolon (the attachment where the peritoneal fold leaves the posterior wall) lies along an oblique line passing across the anterior aspects of the second part of duodenum, head and neck of pancreas, duodenojejunal junction and upper pole of left kidney to reach the splenic flexure. The superior layer of the mesocolon passes anteriorly to reach the posterior aspect of the transverse colon; it then encircles the transverse colon. Reaching the same point of the posterior aspect, it now turns as the inferior layer of the mesocolon and passes to the posterior wall. The superior layer is continuous above and anteriorly with the fourth layer of greater omentum and the inferior layer is continuous below with the right layer of mesentery of small intestine.

Lateral extensions of the transverse mesocolon form the ***phrenicocolic ligament*** on the left and the ***duodenocolic ligament*** on the right. The phrenicocolic ligament extends between the splenic flexure of the transverse colon and the diaphragm; the duodeno colic ligament extends between the second part of duodenum and the hepatic flexure of transverse colon.

Contents of Transverse Mesocolon

- Middle colic vessels and its branches,
- Branches of superior mesenteric plexus,
- Lymphatic vessels and
- Lymph nodes.

Mesentery of the Small Intestine

The mesentery is a broad fan shaped fold of peritoneum which suspends the jejunum and ileum from the posterior abdominal wall. It presents two margins. The vertebral margin is attached to the posterior abdominal wall and is commonly called the ***root of mesentery.*** The other margin is free and invests the jejunum and ileum and is called the ***intestinal border***.

The root of the mesentery lies along a line running diagonally from the ***duodenojejunal flexure*** on the left side of the body of L2 vertebra to the ***sacroiliac joint on the right side***. Its total length is about 15 cm. In its course it crosses over the third part of duodenum, aorta, IVC, right ureter and right psoas major.

The intestinal margin of the mesentery is free and invests the jejunum and ileum and hence is of the same length as that of them (5 m). The two layers split to enclose the jejunum and ileum and are reflected back to the posterior abdominal wall to become continuous above with the peritoneal reflection from the transverse mesocolon (right upper layer) and below with the sigmoid mesocolon (left lower layer).

Contents

- Jejunum,
- Ileum,
- Jejunal and ileal branches of the superior mesenteric vessels,
- Branches of superior mesenteric plexus,
- Fat,
- Lacteals and
- Lymph nodes.

Mesoappendix

The mesentery of the appendix is a small triangular fold of peritoneum around the vermiform appendix. It is attached to the posterior surface of the lower end of the mesentery of small intestine near the ileo caecal junction. It usually reaches the tip of the appendix. The usual contents are the blood vessels, lymphatic vessels and nerves supplying the appendix.

Sigmoid Mesocolon

The left lower layer of mesentery is reflected back from the posterior abdominal wall and enters the pelvic peritoneal cavity, where it becomes continuous with the sigmoid mesocolon. The root of the sigmoid mesocolon forms a shallow ***inverted V***. The apex of the V is at the bifurcation of the common iliac artery. The left end of attachment is over the left psoas major and is placed superiorly. The right end of attachment passes into the pelvis towards the midline till the level of S3 vertebra and is placed inferiorly.

The peritoneum that is reflected from the posterior abdominal wall forms the anteromedial layer of the sigmoid mesocolon; the posterolateral layer of the sigmoid mesocolon is reflected back and becomes continuous with the pelvic peritoneum.

Contents

- Sigmoid vessels and
- Superior rectal vessels.

The left ureter descends into the pelvis behind the apex of the sigmoid mesocolon.

PERITONEUM OF PELVIS

The parietal peritoneum of the posterior surface of the anterior abdominal wall and that lining the posterior abdominal wall continue into the pelvis as the pelvic peritoneum. The pelvic peritoneum then follows the surfaces of the true pelvic viscera and pelvic side walls. The peritoneal folds differ in the two sexes corresponding to the different pelvic viscera.

Peritoneum of the Male Pelvis

The peritoneum lining the posterior abdominal wall enters the pelvic cavity as sigmoid mesocolon and then covers the front and sides of the upper third of rectum and continues to cover the front of middle third of rectum. The peritoneum from the front of middle third of rectum is reflected forwards to the upper ends of seminal vesicles and upper surface of the urinary bladder. Between the rectum and the urinary bladder, the peritoneum dips slightly downwards forming a recess called the ***rectovesical pouch.***

From the apex of the bladder, the peritoneum continues as the median and medial umbilical ligaments to the anterior abdominal wall up to the level of the umbilicus.

From the sides of the upper third of rectum, the peritoneum is reflected to the lateral pelvic wall forming the ***pararectal fossae*** which are bounded laterally by the ***sacrogenital folds***. On either side of the urinary bladder, the peritoneum is reflected to the lateral pelvic wall to form the ***paravesical fossa*** which is bounded laterally by a ridge raised by the ***ductus deferens.***

Peritoneum of the Female Pelvis

In females, the peritoneal lining up to the level of rectum is same as that of males. Further reflection from the rectum differs in females. The peritoneum is reflected from the front of the middle third of the rectum to the posterior fornix of the vagina and thence to the posterior surface of the cervix and body of uterus forming the rectouterine fold. The fold dips downwards forming a recess called the rectouterine pouch. The peritoneum continues over the fundus of the uterus and descends on its anterior surface up to the junction of the cervix and body of uterus and is reflected forwards from there to the upper surface of the bladder forming a shallow vesicouterine pouch. From the apex of the bladder, the peritoneum continues as the median and medial umbilical ligaments to the anterior abdominal wall up to the level of the umbilicus as that of the males.

From the sides of the upper third of the rectum the peritoneum is reflected to the lateral pelvic wall forming the para rectal fossae which are bounded laterally by the rectouterine folds. From the lateral walls of the uterus, the peritoneum is reflected to the lateral pelvic wall as the broad ligament. The broad ligament has anterior and posterior layers which are continuous with each other at the superior border of the ligament. It contains uterine tubes along its superior border and ovaries are attached to its posterior layer by a peritoneal fold called ***mesovarium***. Behind the lateral attachment of the broad ligament on the lateral pelvic wall, the peritoneum forms a shallow depression, the ovarian fossa in which the ovary lies.

On either side of the urinary bladder, the peritoneum is reflected to the lateral pelvic wall to form the ***paravesical fossa*** which is bounded laterally by a ridge raised by the ***round ligament of the uterus***.

BLOOD SUPPLY AND NERVE SUPPLY OF PERITONEUM

The parietal and visceral layers of peritoneum are respectively developed from the ***somatopleural*** and ***splanchnopleural*** layers of the lateral plate mesoderm.

In correlation with their embryological origin, the parietal peritoneum is supplied by arteries supplying the abdominal and pelvic walls. Its nerve supply is derived from the spinal (somatic) nerves which also supply the muscles and skin of the body wall. Hence, parietal peritoneum is sensitive to pain which is referred to the concerned somatic nerve dermatomes.

The visceral peritoneum is considered to be an integral part of the viscera themselves and hence derives its blood supply from the vessels of the respective viscera. Its nerve supply is derived from the sympathetic nerves innervating the concerned viscera and so they are pain insensitive. However, pain in the region of supply of the viscera is felt when the visceral peritoneum is stretched or when its blood supply is compromised as in ischaemia.

FUNCTIONS OF PERITONEUM

- The peritoneum provides a wet and smooth gliding surface for movements of the viscera. The smoothness of the peritoneal surface and the presence of a thin film of fluid between adjacent layers of peritoneum greatly facilitates movements of viscera over one another. Such movements take place as a result of respiration, of peristaltic movements of the intestines, and because of alternate distension and emptying of organs like the stomach, and the urinary bladder.
- The peritoneal fluid is not static but circulates through the peritoneal cavity and is frequently replaced. In general, it tends to flow in an upward direction towards the diaphragm. The fluid is absorbed from the peritoneal cavity into the blood stream, and most of such absorption takes place in the region below the diaphragm.
- Peritoneal fluid is rich in lymphocytes and macrophages which help in the defence mechanism of the body. It is also rich in antibodies which counteract infection.
- When infection develops in an area usually by spread from an inflamed viscus like the appendix, the peritoneum tries to localise the infection and seal it off by forming adhesions around the region. The greater omentum plays a special role in this regard. It has the ability to move to a site of infection (because of its large size and the free mobility of its hanging flap) and tries to wrap itself around the infected region. It is for this reason that the greater omentum has been termed the ***policeman of the abdomen***.
- The greater omentum also acts as a storehouse of fat.
- Some amount of waste products are excreted through the peritoneal fluid. This function is utilised in peritoneal dialysis.
- The various peritoneal folds serve as routes for the passage of vessels and nerves to maintain nutrition to the viscera.
- Intraperitoneal migration of oocyte occurs which enables fertilisation to occur in females with only unilateral uterine tubes.

Clinical Correlation

- ***Peritoneal fluid***
  - Advantage of the rapid transfer of substances between peritoneal fluid and blood is used in the procedure called ***peritoneal dialysis***. In this procedure, a suitable watery solution is made to circulate through the peritoneal cavity before being withdrawn. In this way, harmful substances such as urea can be removed from blood (It may be noted, however, that the technique, used in the past to treat patients with renal failure, has been almost completely replaced by haemodialysis).
  - Under certain conditions, there may be a marked increase in the quantity of peritoneal fluid. Accumulation of fluid in the peritoneal cavity is called ***ascites***. However, because of the size of the peritoneal cavity, almost a litre and a half of fluid may collect before its presence can be recognised on clinical examination. Recognition of ascites is more difficult in an obese person.
  - Fluid that has accumulated in the peritoneal cavity may be removed through a cannula introduced through the abdominal wall. The procedure is called ***paracentesis***. It may be done through the linea alba or through one of the flanges of abdomen.
  - The large absorptive area of peritoneum poses a serious danger when infection develops in the peritoneal cavity (***peritonitis***). Toxins are rapidly absorbed into blood leading to toxaemia. Because of this reason, generalised peritonitis can be a life-threatening condition.
  - Occasionally surgeons use the greater omentum to close perforations in the gut, or to cover the area of an intestinal anastomosis.
  - In a supine position, peritoneal fluid tends to gravitate to the sub diaphragmatic region (especially into the right posterior subphrenic space). As absorption of substances is more in this region, it may be harmful when toxins tend to get absorbed here. Hence, absorption of toxins can be minimised by placing the patient in a position in which the back is raised to an angle of 45 degrees (Fowler's position). In this position, the fluid gravitates into the pelvis where absorption is much less pronounced.

contd…

Clinical Correlation *contd…*

- ***Pain in peritoneal infection***
  - Abdominal infections are accompanied by pain.
  - The visceral peritoneum, supplied by autonomic nerves, is much less sensitive to pain than the parietal peritoneum that is innervated by somatic nerves. Pain arising in the visceral peritoneum is stimulated mainly by stretching, and tends to be poorly localised. In contrast, pain caused by inflammation of an area of parietal peritoneum can be accurately localised.
  - Embryologically, the gut is a midline structure. Because of this, visceral pain arising in the gut is at first felt over the midline.
    - Pain arising in the stomach and duodenum is referred to the epigastrium.
    - Pain from the rest of the small intestine, the appendix and the ascending colon is referred to the area around the umbilicus; and from the rest of the gut to the hypogastrium.
    - In a case of acute appendicitis, pain is first felt around the umbilicus. Only when the parietal peritoneum gets involved pain, shifts to the right iliac fossa.
    - The peritoneum lining the undersurface of the diaphragm is innervated by the phrenic nerve, the fibres of which are derived from the same spinal segments (C3, 4, 5) which supply the skin of the shoulder. Pain arising from a subdiaphragmatic infection can therefore be referred to the shoulder.
  - Inflammation of the parietal peritoneum also makes it very sensitive to stretching. This forms the basis of a clinical test called ***rebound tenderness***.
    - If a finger is pressed over an inflamed area of abdomen and then suddenly removed, abrupt stretching of the abdominal wall (as a result of rebound) leads to severe pain.
- ***Importance of peritoneal spaces (isolated pockets in peritoneum):*** It was seen earlier that the peritoneal cavity is divided into various parts/spaces/recesses as a result of the presence of many folds. Because of this, infection can occur in localised pockets of peritoneum, especially in the ***subphrenic spaces*** that surround the liver.
  - The right posterior space (or right subhepatic space) is the most dependent part of the peritoneal cavity (in the supine position). It is closely related to the right kidney and is therefore called the ***hepatorenal pouch*** (also called ***Morison's pouch***). This is the commonest site of a ***subphrenic abscess***. Infection may spread to this space from the gall bladder, the vermiform appendix or from any other organ in the region. Further, infection can spread through the diaphragm into the pleural cavity.
  - Fluid may accumulate in the ***lesser sac***. Normally such fluid flows into the hepatorenal pouch through the aditus to the lesser sac, but it remains in the lesser sac if the aditus is obstructed by adhesions. Entry of fluid into the lesser sac may result from perforation of an ulcer on the posterior wall of the stomach. Accumulation of fluid in the lesser sac is a frequent complication of inflammation of pancreas (***pancreatitis***) and such a collection is referred to as a ***pseudopancreatic cyst***.
  - ***Rectouterine pouch:*** Peritoneum on the front of the rectum is reflected on to the upper most part of the vagina forming the rectouterine pouch (The term is sanctified by long usage but the pouch is really rectovaginal).
    - Clinicians often refer to this pouch as the ***pouch of Douglas***.
    - In a sitting or standing person, this pouch is the most dependent part of the peritoneal cavity and fluid or pus tends to collect here when there is infection.
    - The pouch is bounded, posteriorly, by the rectum; anteriorly, by the posterior aspect of uterus and the uppermost part of vagina (posterior fornix); and inferiorly by the rectovaginal fold of peritoneum.
    - It is important to know that the floor of the pouch lies only 5.5 cm from the anus. It can be palpated, and drained, either through the posterior fornix of vagina or through the rectum.
    - In the male, the rectouterine pouch is replaced by the rectovesical pouch (which lies between the rectum and the urinary bladder). The floor of this pouch is 7.5 cm from the anus.
- ***Internal hernia:*** The abdominal contents not only herniate to outside of the abdominal cavity through areas of weakness in the abdominal wall, but also in some cases, coils of gut or greater omentum, may herniate into a localised part of the peritoneal cavity itself. Such an occurence is called ***internal hernia***. Such herniation can take place through the aditus to the lesser sac.

  It can also take place into one of the peritoneal recesses present in relation to the duodenum or to the caecum. An internal hernia might get strangulated. A surgeon has to know the positions of the recesses and has to remember that some of the folds of peritoneum forming the boundaries for the recesses contain blood vessels for appropriate management.
- ***Laparotomy and laparoscopy***
  - An operation that opens the peritoneal cavity is called ***laparotomy***. The procedure may be preliminary to surgery on any organ, or may be used to inspect the interior of the abdominal cavity in cases where diagnosis is otherwise difficult.
  - However, it is now possible to inspect the interior of the peritoneal cavity by introducing an instrument called the **laparoscope** through a small opening in the abdominal wall. The procedure is called **laparoscopy**. Several abdominal surgical procedures are now being carried out through such instruments.

Multiple Choice Questions

1. In the embryo, the gut is suspended from the dorsal wall by the:
   a. Dorsal mesogastrium
   b. Ventral mesogastrium
   c. Mesentery
   d. Mesogut

2. The part of dorsal mesogastrium passing from spleen to posterior abdominal wall becomes lienorenal because:
   a. Kidney insinuates between its layers
   b. Its attachment shifts from midline to left
   c. Spleen moves closer to kidney
   d. The tissue to which the ligament is attached belongs to the nephrogenic cord

3. The epiploic foramen is bounded superiorly by:
   a. Caudate process of liver
   b. Quadrate lobe
   c. Fundus of gall bladder
   d. Porta hepatis

4. The most dependent part of the peritoneal cavity in the supine position is:
   a. Right subhepatic space
   b. Right extrahepatic space
   c. Right suprahepatic space
   d. Omental bursa

5. Small recesses of the peritoneum are important because they are sites of:
   a. Internal herniae
   b. Vascular bleed
   c. Calcification
   d. Expansion and bullous formation

ANSWERS

1. a **2.** b **3.** a **4.** a **5.** a

Clinical Problem-solving

Case Study 1: A 34-year-old man complains of excruciating pain in the abdomen. Peritoneal inflammation is suspected.
- If the man has pain over the shoulder, which part of his peritoneum is likely to be involved?
- Which particular test would you try to do for checking if the parietal peritoneum is involved?

Case Study 2: A 44-year-old man has pus collection in his Morison's pouch.
- Which part of his gut should be primarily involved to cause this condition?
- What is the anatomical topography of Morison's pouch? Name a similar dependent pouch in the erect posture.

(For solutions see Appendix).

Chapter 17

Viscera of Digestive Tract—I: Oesophagus, Stomach and Intestines

Frequently Asked Questions

- Discuss in detail on: (a) Stomach, (b) Duodenum.
- Write briefly on: (a) Blood supply of stomach, (b) Lymphatic drainage of stomach, (c) Structures forming stomach bed, (d) Descending part (second) part of duodenum, (e) Differences between jejunum and ileum, (f) Mesentery, (g) Caecum, (h) Vermiform appendix.

The abdominal cavity is predominantly occupied by the viscera of the digestive tract. These viscera can be classified into two groups—(1) viscera of the digestive tract proper and (2) viscera related to digestive tract, but with additional functions. This chapter deals with the first group, namely viscera of the digestive tract proper.

The digestive tract can be defined as a long tube whose different portions are variably dilated and form the different organs of the gastrointestinal system. The uppermost portion of the tube lies in the head region and some parts of the tube traverse the neck and the thoracic cavity to reach the abdominal cavity. Thus, the mouth lies within the head; the pharynx lies in the neck and the upper oesophagus traverses the neck and the thoracic cavity.

ABDOMINAL PART OF OESOPHAGUS

Other names of oesophagus: Gullet, food pipe, swallow. Oesophagus (Greek.oisophagos=gullet; old Greek name meaning 'I eat'; phagos=to eat) is the narrow tube of the alimentary canal that joins the pharynx to the stomach. It begins at the level of the lower border of cricoid cartilage (in the neck) and ends at the cardiac orifice of the stomach. It has two parts, thoracic and abdominal (though only two parts have been customarily described, it is not wrong to talk of three parts, namely the ***cervical***, ***thoracic*** and ***abdominal parts***). The cervical part has been considered in the section on head and neck and the thoracic part in the section on thorax.

The thoracic part passes downwards along the posterior border of left lung to reach the diaphragm. The diaphragmatic orifice through which the oesophagus enters the abdomen is located at the level of the 10th thoracic vertebra, slightly to the left of the median plane. The abdominal part, which commences at this orifice, passes downwards and to the left to end at the level of the 11th thoracic vertebra by joining the cardiac end of the stomach. The abdominal part is about 1–2.5 cms long (the total length of the oesophagus is about 25 cm). It grooves the left lobe of liver anteriorly and rests on left crus of diaphragm, left inferior phrenic vessels and left greater splanchnic nerve (Fig. 17.1)

The oesophagus is covered by connective tissue and visceral peritoneum which contains the anterior and posterior vagal nerves. The anterior vagus is closely related to the longitudinal muscle coat of the oesophagus and the posterior vagus is less closely applied to the oesophageal muscle, which makes its identification during surgery easier. Histological studies of the oesophagocardiac junction have failed to reveal the presence of an anatomical sphincter. However, the musculature here acts as a physiological sphincter that normally keeps the cardiac orifice closed, but relaxes to allow passage of swallowed food. The ***phrenoesophageal ligament***, which is a thickening of transversalis fascia tethers the abdominal part of oesophagus to the diaphragm.

The abdominal part of oesophagus is supplied by the oesophageal branches of left gastric artery and thoracic aorta and drained by left gastric veins and short gastric veins. The lymph drains into left gastric nodes and para-aortic nodes.

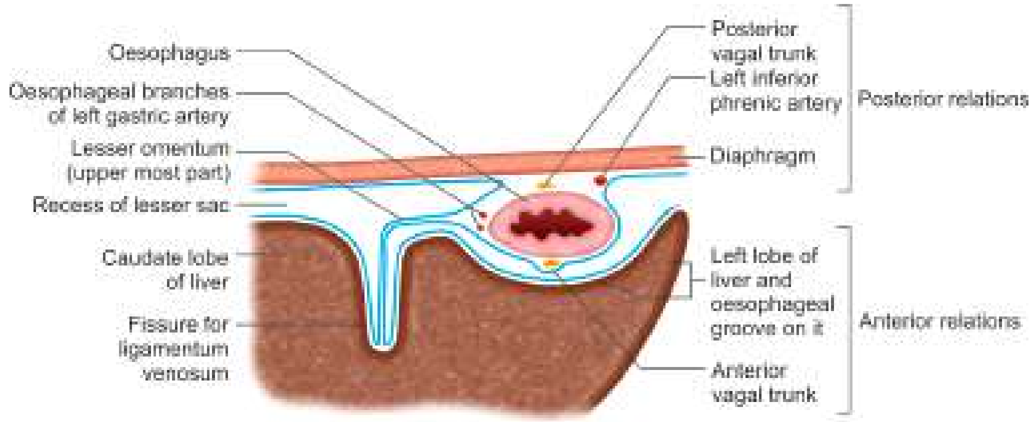


Fig. 17.1: Schematic transverse section through the abdominal part of the oesophagus to show some related structures

Clinical Correlation

- ***Achalasia cardia:*** In some persons failure of the sphincter to relax leads to dysphagia. The defect is believed to be a functional one and is referred to as ***achalasia cardia*** (achalasia=failure to relax). Non-relaxation of the sphincter leads to constriction of the lumen. The lumen appears to dwindle in size from above downwards (as it is normal above) and is seen as the ***'rat tail' appearance*** in barium swallow radiographs.
- ***Oesophagitis:*** Normally, acid in the stomach does not regurgitate into the oesophagus. However, in some cases such regurgitation occurs and results in inflammation of the oesophagus (***oesophagitis***), and formation of ulcers which can lead to cancer at the lower end of the oesophagus.
- Hiatus hernia
- Oesophageal varices
- Abnormal communications may be seen between parts of the gut and other cavities near them. Such communications are most common in regions where the gut normally undergoes a process of septation. Defects in the process of separation of the trachea from the oesophagus lead to various types of ***tracheoesophageal fistulae***.

Histology

Gut

Entire gastointestinal tract extending from oesophagus to anal canal is basically formed of four layers.

1. ***Mucosa:***
   - It consists of lining ***epithelium*** (main function is protection, absorption and secretion).
   - It contains underlying ***lamina propria*** which is made up of connective tissue containing glands, blood and lymphatic vessels (main function is transport of absorbed substances and providing immunity).
   - It contains ***muscularis mucosa*** made up of two layers of smooth muscle (inner circular and outer longitudinal layers which are responsible for movement and folding of mucosa).

contd...

Histology *contd...*

2. ***Submucosa*** made up of dense irregular connective tissue containing blood vessels, lymphatic vessels, nerve plexus (Meissner's plexus) and occasional glands.
3. ***Muscularis externa*** made up of inner circular and outer longitudinal layer; contains Auerbach's/Myenteric nerve plexus between two layers of smooth muscle (this layer is responsible for peristaltic contractions).
4. ***Serosa*** made up of simple squamous epithelium, the mesothelial lining (peritoneum) over a layer of loose connective tissue. If non-serous adventitia is present, it is made up of only loose connective tissue without peritoneum. This layer is supportive and protective in function.

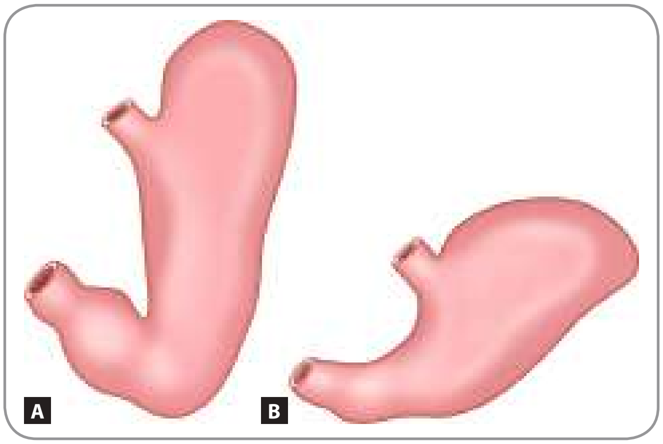
STOMACH

Other names: Gaster, ventriculus.

The stomach (Greek.stomachos=mouth bag) is a sac-like structure that serves as a reservoir of swallowed food, and plays an important part in digesting it. It has a capacity of about 50 ml at birth, 1000 ml at puberty and 1500 ml in adults. It is the most dilated part of the alimentary canal. Its shape varies considerably depending upon whether it is full or empty; and is also influenced by posture. Commonly, the stomach is ***J-shaped*** having a long vertical part (above and to the left) and a shorter horizontal part (below and to the right) (Fig. 17.2A). Sometimes, the stomach may be orientated almost transversely. This is described as a ***steer-horn*** type of stomach (Fig. 17.2B).

LOCATION

The stomach occupies the epigastric, left hypochondriac and umbilical regions (Fig. 17.3).



Figs 17.2A and B: **A.** J-shaped stomach **B.** Steer-horn stomach

PRESENTING PARTS

The stomach has ***two orifices***—cardiac and pyloric; ***two curvatures***—lesser and greater and ***two surfaces***—anterosuperior and posteroinferior.

Orifices

1. ***Cardiac orifice:*** The opening of the oesophagus into the stomach is the cardiac orifice. As this end lies close to the heart it is named the ***cardiac orifice***. It is 40 cm from the incisor teeth and present about 2.5 cm left of the midline at the level of 7th costal cartilage (T11 vertebra), 10 cms deep to the anterior abdominal wall.
2. ***Pyloric orifice:*** The pylorus (or pyloric orifice) lies about 1 cm (half inch) right of the midline, at the level of the transpyloric plane (lower end of L1 vertebra). However, when the stomach is full the pylorus may move downwards to the level of the second lumbar vertebra, or even the third vertebra. The caudal end of the stomach is continuous with the duodenum. This end is called the ***pyloric end***, or simply the ***pylorus*** (Greek.pyloron=gate keeper).

Cardiac orifice does not have an anatomical sphincter whereas pyloric orifice has an anatomical sphincter formed by the thickening of the muscle coat.

Curvatures

The concave upper border is called the ***lesser curvature*** (or simply the lesser curve) and the convex lower border is called the ***greater curvature*** (or simply the greater curve). The lesser curvature faces to the right in its upper part, and upwards in its lower part. It is more or less 'J' shaped and has a dependent part called the ***incisura angularis***. At the lesser curvature, the anterior and posterior layers of peritoneum become continuous with the lesser omentum. The lesser omentum contains the anastomosis between right and left gastric arteries within its layers (Fig. 17.3).

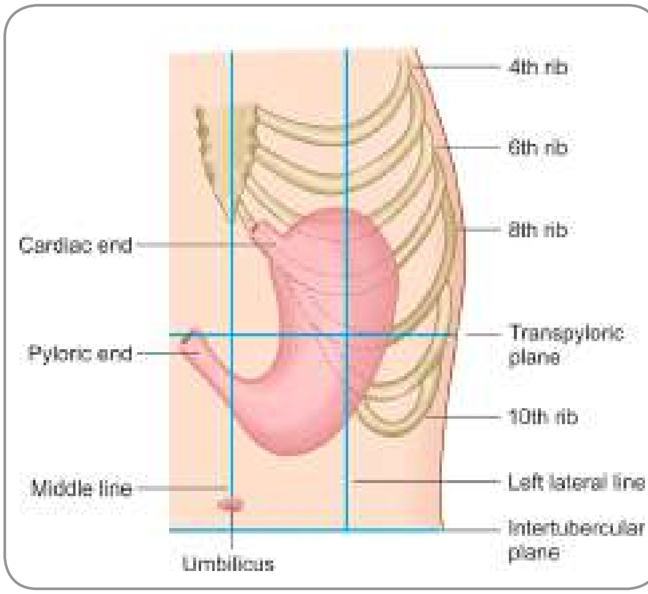


Fig. 17.3: Surface projection of the stomach

Proceeding from the cardiac end to the pyloric end, the convexity of the greater curvature has a part facing upwards, then a part facing the left side, and finally a part facing downwards. At the greater curvature the anterior and posterior layers of peritoneum become continuous with the gastrosplenic ligament, gastrophrenic ligament and the greater omentum. The greater omentum contains the anastomosis between right and left gastroepiploic arteries within its layers.

Surfaces

The stomach is covered by peritoneum on both the anterosuperior and posteroinferior surfaces.

1. ***Anterosuperior surface:*** A considerable part of the stomach lies above the costal margin (Figs 17.3, and 17.4).

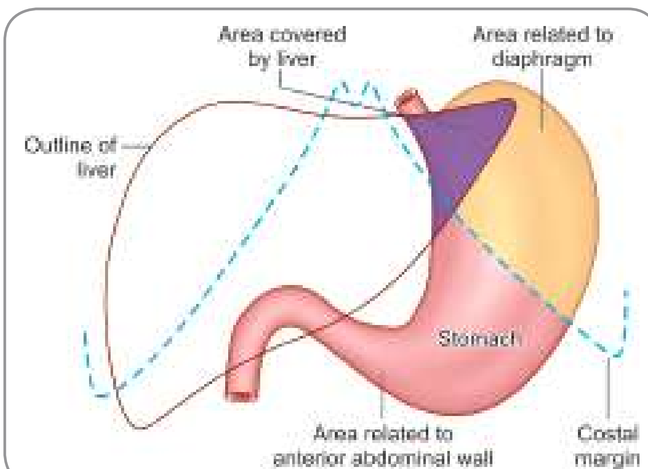


Fig. 17.4: Scheme to show the chief structures in contact with the anterior surface of the stomach

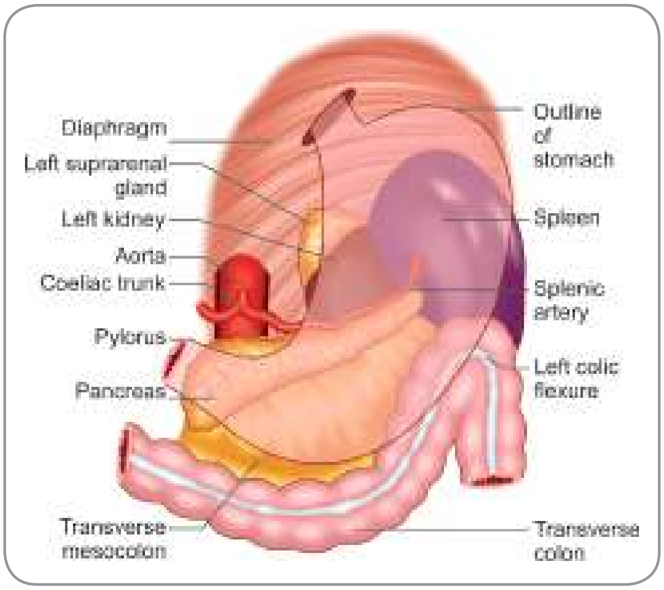


Fig. 17.5: Scheme to show the structures forming the stomach bed. Note that the spleen is separated from the stomach by the gastrosplenic ligament, and is really related to the 'anterior' surface. The remaining structures are separated from the posterior surface of the stomach by the lesser sac

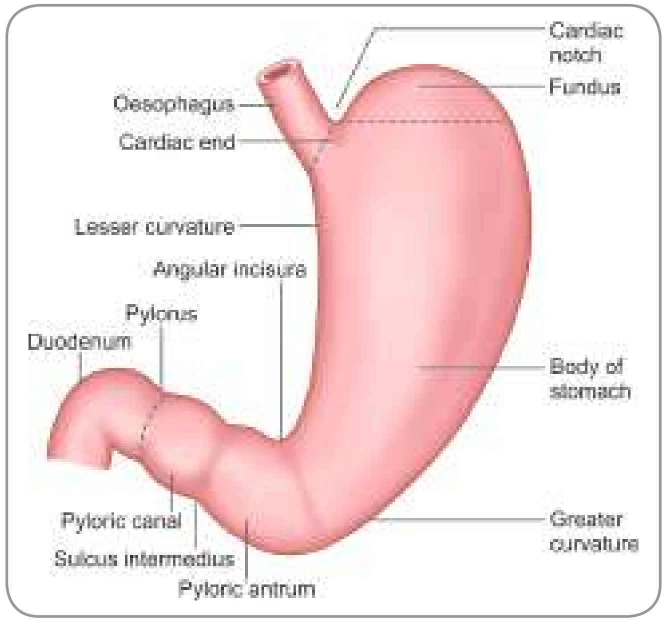


Fig. 17.6: Subdivisions of the stomach

Most of this part of the anterior surface is in contact with the diaphragm that separates the stomach from the left pleura and lung. Part of the anterior surface of the stomach is in contact with the liver, and part of it with the anterior abdominal wall (Fig. 17.4). The left end faces backwards and to the left and comes in contact with the spleen. When empty, this surface is related to the transverse colon (Fig. 17.5). The whole of this surface is covered by peritoneum.

2. ***Posteroinferior surface:*** The posteroinferior surface of the stomach is separated by the cavity of the lesser sac from several structures lying on the posterior abdominal wall. These structures are described collectively as forming the ***stomach bed*** (Fig. 17.5). They are:
   - The left crus and lower fibres of the diaphragm
   - The left inferior phrenic vessels
   - The left kidney
   - The left suprarenal gland
   - The anterior surface of pancreas
   - The left colic flexure and the transverse mesocolon
   - The spleen (the upper left part of the stomach)
   - The splenic artery

PARTS OF THE STOMACH

The stomach is divided into a number of parts (Fig. 17.6) namely, ***fundus***, ***body*** and ***pylorus***. At the junction of the left margin of the oesophagus with the greater curvature of the stomach, there is a deep notch called ***incisura cardiaca***. The upward convexity of the adjoining part of the greater curvature of the stomach lies above the level of the cardioesophageal junction. This part of the stomach is called the ***fundus***. The highest part of the stomach is the fundus. It reaches the left fifth intercostal space, just below the nipple.

The part of the stomach above and to the left of the incisura angularis is more or less rounded and is called the ***body***. The part of the stomach to the right of the incisura angularis is the ***pyloric part***. It consists of a relatively dilated left part (continuous with the body) called the ***pyloric antrum;*** and a narrower right part called the ***pyloric canal***. The greater curvature may show slight bulgings corresponding to the pyloric antrum and canal. These bulgings may be separated by a notch called the ***sulcus intermedius***. The position of the pyloric orifice is indicated on the surface by a groove that marks the junction of the stomach with the duodenum and by the ***prepyloric vein of Mayo***.

BLOOD SUPPLY

All the arteries supplying the stomach are derived from the coeliac trunk or one of its branches (Fig. 19.3). Along the lesser curvature (within the two layers of the lesser omentum) are the right and left gastric arteries. The left gastric artery is a direct branch of the coeliac trunk. The right gastric artery is a branch of the hepatic artery. Along the greater curvature (between the 2 layers of the greater omentum), there are the right and left gastroepiploic arteries. The right gastroepiploic artery arises from the gastroduodenal artery, while the left gastroepiploic artery is a branch of the splenic artery. The stomach also receives short gastric arteries which are branches of the splenic artery.

The veins from the stomach drain into the splenic and superior mesenteric veins. The right and left gastric veins drain into the portal vein directly and the right gastric vein receives the prepyloric vein of mayo. The short gastric veins and left gastroepiploic vein drain into the splenic vein and the right gastroepiploic vein drains into the superior mesenteric vein. This blood passes through the portal vein to the liver. In other words, the veins of the stomach form part of the portal venous system.

NERVE SUPPLY

The stomach is supplied by sympathetic and parasympathetic nerves. The sympathetic nerves are derived from the coeliac plexus formed from T5 to T12 spinal segments via greater and lesser splanchnic nerves. Their functions are sensory, vasoconstrictor to the vessels and cause pyloric constriction. They reach the stomach by running through autonomic plexuses found along the arteries.

The parasympathetic nerves are derived from the vagus nerves. The anterior vagus (left vagus) divides into anterior gastric and hepatic branches. The main branch of anterior gastric branch (anterior nerve of latarjet) supplies the body, fundus and pyloric antrum. The hepatic branches run between the layers of the lesser omentum to supply the liver and its pyloric branches turn down to reach the pylorus. The posterior vagus (right vagus) gives two main branches, gastric (posterior nerve of latarjet) and coeliac. The gastric branch supplies upper and posterior part of body of stomach till the pyloric antrum. Its most cranial branch is called ***criminal nerve of Grassi*** (named after the 19th-20th century Italian physician and zoologist Giovanni Battista Grassi) as it might be missed during vagotomy. The coeliac branches reach the coeliac plexus. The parasympathetic supply is secretomotor, motor to stomach muscles and relaxor to pyloric sphincter.

Histology

Oesophagus

- ***Mucosa*** has non-keratinised stratified squamous epithelium and underlying lamina propria that contains oesophageal cardiac glands in the lower part of oesophagus; these glands protect it from regurgitated gastric contents. Muscularis mucosa is made up of a thick single longitudinal layer of smooth muscle and no circular layer is present.
- ***Submucosa*** contains oesophageal glands (compound tubuloalveolar mucous glands).
- ***Muscularis externa***—upper 1/3rd contains only skeletal muscle, middle 1/3rd contains both skeleletal and smooth muscle and lower 1/3rd contains only smooth muscle; arranged in two layers as inner circular and outer longitudinal layers; receive both somatic and autonomic nerve supply from vagus nerve.
- ***Adventitia*** is made up of loose connective tissue without peritoneum.

Stomach (Fundus)

- ***Mucosa*** is lined by simple columnar epithelium (surface mucous cells) which secretes insoluble mucus that lubricates and protects epithelial surface from acid content of chyme. Invaginations in the epithelium are called ***gastric pits***/foveolae gastricae.
- ***Lamina propria***
  - Has long tubular fundic glands which open into the gastric pits.
  - Fundic glands contains chief/zymogenic cells, parietal cells, mucous neck cells and enteroendocrine cells.
    - ***Mucous neck cells*** are low columnar cells in the neck region and secrete soluble mucus.
    - ***Chief/zymogenic/peptic cells*** are small cuboidal cells that are found in the deeper part of fundic glands. They contain basophilic cytoplasm and have zymogen granules in the apical parts of cytoplasm. They secrete pepsinogen, lipase and amylase (pepsin is produced by action of gastric juice on pepsinogen).
    - ***Parietal/oxyntic cells*** are large pyramidal cells containing acidophilic cytoplasm. They secrete hydrochloric acid and the gastric intrinsic factor (for absorption of vitamin B12 in the ileum which is essential for erythropoiesis).
    - ***Enteroendocrine cells*** are unicellular cells found in the basal parts of the glands. They belong to the APUD cell series. They secrete gastrin, somatostatin and histamine.
  - Muscularis mucosae is made up of inner circular and outer longitudinal layers.
- ***Submucosa*** is made up of dense irregular connective tissue containing blood vessels, lymphatic vessels and Meissner's plexus.
- ***Muscularis externa*** is made up of inner oblique, middle circular and outer longitudinal layers. It contains the myenteric nerve plexus between the circular and longitudinal layers. It produces a churning movement that mixes food with the gastric secretions.
- ***Serosa*** is the outermost layer made up of loose connective tissue covered by peritoneum.

Stomach-Pylorus

- Histologic features are same as in the fundic part of stomach.
- Has deep gastric pits.
- Lamina propria is rich in mucous secreting pyloric glands.
- Middle circular muscle layer is thickened at the distal pyloric antrum to form the pyloric sphincter.

Development

Stomach

The stomach develops from the caudal part of the foregut. This part forms a ***fusiform dilatation***, with two borders–ventral and dorsal, two surfaces—left and right surfaces. The ventral border is attached to the septum transversum and anterior abdominal wall by the ***ventral mesogastrium***. The dorsal border is attached to the posterior abdominal wall by the ***dorsal mesogastrium***. The liver forms within the folds of the ventral mesogastrium and divides it into the ***lesser omentum*** (between liver and stomach), ***coronary ligaments*** and ***falciform ligament*** (between the liver on one hand and the diaphragm and anterior abdominal wall on the other). Similarly the dorsal mesogastrium is divided by spleen into the ***gastrosplenic*** (between stomach and spleen) and the ***lienorenal*** ligaments (between spleen and posterior abdominal wall). As a result of differential growth of the walls of stomach, the dorsal border grows more than the ventral border and forms the ***greater curvature*** of stomach, while the ventral border forms the ***lesser curvature***.

Rotation of stomach: The stomach undergoes rotation through 90 degrees around the vertical axis. As a result, the greater curvature with the dorsal mesogastrium is shifted to the left side and the lesser curvature with the ventral mesogastrium is shifted to the right side. The original left surface becomes anterior or anterosuperior surface and the right surface becomes posterior or posteroinferior surface.

LYMPHATIC DRAINAGE

The stomach is divided into four regions for the purpose of lymphatic drainage. The fundus and left half of body of stomach drain into the pancreaticosplenic nodes. The upper right half of body of stomach drains into the left gastric nodes. The lower right half of body of stomach drains into the right gastroepiploic nodes. The pylorus of the stomach drains into pyloric nodes, which then drains into hepatic nodes. The lymphatics from these nodes reach the coeliac nodes ultimately.

Clinical Correlation

- Inflammation of the stomach is ***gastritis***. An instrument that is used to visualise the interior of the stomach is a ***gastroscope***, and the procedure is called ***gastroscopy***.
- Gastric pain is referred to the epigastrium. It is produced by spasm of muscle, or by overdistension of the organ. Irritation of gastric mucosa in gastritis can cause abdominal discomfort, nausea and vomiting.
- The congenital thickening of the pyloric sphincter, causing narrowing of the lumen is called ***congenital hypertrophic pyloric stenosis***. It can be successfully treated by surgically incising the thickened mass of muscle longitudinally. The incision is carried into the entire thickness of the muscle without damaging the mucosa.
- ***Gastric ulcer:*** The normal gastric mucosa is resistant to the action of acid present in the stomach. However, in some cases,

contd...

Clinical Correlation *contd...*

the mucosa gets eroded leading to the formation of a gastric ulcer. An ulcer can be a source of pain, and of bleeding which can at times be serious. As the ulcer erodes further into the thickness of the stomach wall, it can result in adhesion of the stomach wall to surrounding structures, or to perforation of the wall.

Perforation of an ulcer located on the posterior wall of the stomach can lead to leakage of contents into the lesser sac. It can also lead to erosion of the pancreas, and even of the splenic artery (the latter leading to fatal haemorrhage). Perforation of an ulcer on the anterior wall of the stomach can lead to escape of gastric contents into the greater sac. Such an ulcer can adhere to and involve the liver substance. Patients of gastric ulcer are treated by drugs that block acid secretion.

- ***Vagotomy:*** The cutting of vagus nerve is called vagotomy. If the trunks of vagus nerves are cut, it is called ***truncal vagotomy***. If the anterior and posterior nerves of latarjet are cut, it is called ***selective vagotomy***. In these two procedures, the pyloric antrum branches are also cut, leading to defective gastric emptying. So, the pyloric branches are preserved and only the gastric branches of nerve of latarjet are cut in highly selective vagotomy. If the criminal nerve of grassi is left out, then the fundic glands will keep functioning. So it has to be looked for and ligated properly to get a total relief from gastric secretions.
- ***Gastric carcinoma:*** The stomach is a frequent site of carcinoma. The cancer cells can spread through lymphatics. Surgical treatment involves removal of the entire stomach (***total gastrectomy***). The lower end of the oesophagus and the first part of the duodenum are also removed. Continuity of the gut is established by anastomosing the oesophagus with the jejunum. In cases of suspected gastric ulcer or carcinoma, the interior of the stomach can be viewed through a gastroscope. Biopsies can also be taken through the instrument. Radiologically, the gastric mucosa can be studied by taking skiagrams after a barium meal.
  - ***Troisier sign:*** The enlargement of left supraclavicular nodes in gastric carcinoma is called Troisier's sign.
  - ***Sister Joseph's nodules:*** The nodules found near umbilicus, due to the spread of cancer cells in advanced gastric carcinoma stage.

INTESTINE

The part of the alimentary canal extending from the stomach to the anus is collectively called the ***intestine***. The intestine (Latin.intestinum=internal, inward) is divided into the ***small intestine*** and the ***large intestine*** on the basis of anatomical and functional considerations.

SMALL INTESTINE

Other name: Intestinum tenue.

The small intestine is a tube about five metres long. It is divided into three parts. These are (in craniocaudal sequence): the ***duodenum,*** the ***jejunum*** and the ***ileum***. The duodenum continues as the jejunum at the duodenojejunal flexure. The proximal two fifths distal to the duodenojejunal flexure is the jejunum and the distal three fifths is the ileum. The duodenum is not covered by peritoneum wholly and is mostly retroperitoneal, whereas the jejunum and ileum are covered by peritoneum completely.

Duodenum

Other name: C intestine.

The duodenum (Latin.duodeni=twelve; old Greek name for this viscus was Dodeka daktulon meaning 12 fingers, denoting its length of 12 fingers breadth) forms the first 25 cm (10 inches) of the small intestine. It is in the form of a roughly C-shaped loop which is retroperitoneal and, therefore, fixed to the posterior abdominal wall. It is continuous at its cranial end with the pylorus of the stomach. The junction between the two is called the ***pyloroduodenal junction***. At its caudal end, the duodenum becomes continuous with the jejunum at the ***duodenojejunal flexure***.

The duodenum is subdivided into four parts as follows (Fig. 17.7):

First Part of Duodenum

Other name: Pars superior.

The ***first or superior part*** begins at the pylorus and passes backwards, upwards and to the right. It is about 5 cm long. The junction of the first and second parts of the duodenum is called the ***superior duodenal flexure***. It is present at the level of L1 vertebra. The lesser omentum is attached to its upper border and the greater omentum to its lower border. The first 2 or 3 cm, known as the duodenal 'cap', has a tendency to be seen separately as a triangular, homogeneous area during contrast radiology. It is a more distensible part and seen as an isolated triangular gas shadow to the right of the first or second lumbar vertebra in plain radiograph.

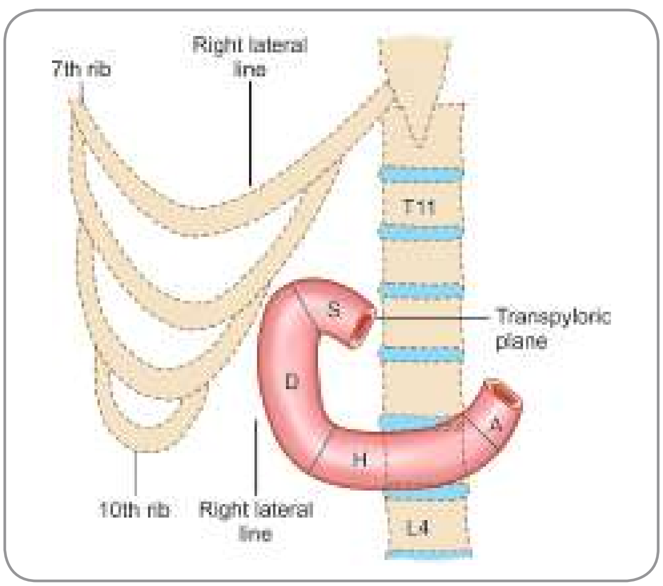


Fig. 17.7: Parts of the duodenum and their surface projection
Key: S. Superior part **D.** Descending part **H.** Horizontal part **A.** Ascending part

Relations

- ***Anteriorly***
  - Liver (quadrate lobe)
  - Gallbladder.
- ***Posteriorly***
  - Inferior vena cava, separated by a part of the lesser sac.
  - The bile duct, the portal vein and the gastroduodenal artery.
  - ***Superiorly:*** Aditus to the lesser sac.
  - ***Inferiorly:*** Pancreas (head and neck).

Peritoneal Relations

Most of the duodenum is retroperitoneal and is covered by peritoneum only on its anterior aspect.

The proximal portion of the superior part of the duodenum is however covered on both its anterior and posterior aspects by peritoneum (continuous with that on the anterior and posterior surfaces of the stomach).The two layers covering the proximal part of the duodenum meet above to form the extreme right part of the lesser omentum. This part of the lesser omentum passes to the liver as the right free margin. Immediately posterior to the right free margin of the lesser omentum is the aditus to the lesser sac. Peritoneum lining the posterior surface (of the proximal half) of the superior part of the duodenum is reflected onto the front of the pancreas. This reflection forms the right margin of the lesser sac in this position.

Second Part of Duodenum

Other name: Pars descendans.

The ***second or descending part*** is about 8 cm long. It passes downwards, with a slight convexity to the right. It extends from L1 vertebra to L3 vertebra. The junction between the second and third part is called the ***inferior duodenal flexure***. It is retroperitoneal with the peritoneum covering only its anterior aspect.

Relations

- ***Anteriorly***
  - Crossed by transverse colon and transverse mesocolon
  - Part above transverse colon is overlapped by the liver
  - Part below the transverse colon is overlapped by coils of jejunum.

- ***Posteriorly***
  - Medial margin of right kidney and right renal vessels
  - Right edge of inferior vena cava
  - Right psoas major.
- ***Medially (or left)***
  - Head of pancreas
  - Bile duct
  - Pancreatic ducts.
- ***Laterally (or right)***
  - Right colic flexure

Interior of Duodenum

The interior is marked by transverse mucosal folds (plicae circulares/valves of Kerckring), which are quite pronounced beginning with the distal part of the first part of duodenum. In the posteromedial portion of the second part, the mucous membrane also shows a prominent vertical fold. The lower part of this fold is marked by a projection called the ***major duodenal papilla***, which is present about 8–10 cm distal to the pylorus. The papilla bears an opening of a common channel, the hepatopancreatic ampulla, into which the bile duct and the main pancreatic duct open. About 2 cm cranial to, and in front of, the major duodenal papilla, there is a smaller projection called the ***minor duodenal papilla***. The minor papilla has an opening for the accessory pancreatic duct.

Third Part of the Duodenum

Other name: Pars horizontalis.

The ***third or horizontal part*** is about 10 cm long. It passes from right to left (with a slight downward convexity) and crosses the midline at the level of the third lumbar vertebra.

Relations

- ***Anteriorly***
  - Crossed by mesentery and superior mesenteric vessels.
  - Covered by transverse mesocolon, and sometimes by transverse colon, and/or loops of jejunum.
- ***Posteriorly***
  - Right psoas major
  - Inferior vena cava
  - Abdominal aorta
  - Right ureter
  - Right testicular or ovarian vessels
  - Inferior vena cava and aorta separate it from vertebra L3.
- ***Above:*** Pancreas.
- ***Below:*** Coils of jejunum.

Fourth Part of the Duodenum

Other name: Pars ascendans.

The ***fourth or ascending part*** is about 2 cm long. It runs upwards and to the left and ends by joining the jejunum at the duodenojejunal flexure.

Relations

- ***Anteriorly***
  - Transverse mesocolon
  - Transverse colon
- ***Posteriorly***
  Left psoas major separated by:
  - Left sympathetic trunk
  - Left renal and testicular vessels
  - Inferior mesenteric artery
- ***Above:*** Body of pancreas
- ***Below:*** Jejunum
- ***Right:*** Abdominal aorta
- ***Left:*** Left kidney and ureter.

Ligament of Trietz

The fourth part is covered with peritoneum in its end near the duodenojejunal flexure. A fold of peritoneum containing fibromuscular tissue, called ligament of Treitz suspends the duodenojejunal flexure from the posterior abdominal wall. It may sometimes contain a small slip of muscle called the ***suspensory muscle of the duodenum*** which has skeletal muscle fibres that attach to the left crus of the diaphragm in the upper one-third, smooth muscle fibres from duodenum in the lower one-third and fibrous tissue bridging these two surrounds the coeliac artery, in the middle one-third.

Blood Supply

The first part of the duodenum, and the upper portion of the second part (cranial to the major duodenal papilla) are derived from foregut and hence are supplied by branches of the coeliac trunk (hepatic, right gastric, supraduodenal, right gastroepiploic and superior pancreaticoduodenal arteries).The remaining part of the duodenum (caudal to the major duodenal papilla) is derived from the midgut. This part is supplied by the inferior pancreaticoduodenal branch of the superior mesenteric artery.

The veins of the duodenum end in the splenic and superior mesenteric veins. Some veins end directly in the portal vein.

Nerve Supply

The duodenum receives sympathetic supply from coeliac and superior mesenteric plexus (T5-T10) and parasympathetic nerve fibres from the vagus nerves.

Lymphatic Drainage

The lymph from the duodenum drains into the pancreaticoduodenal nodes. From here lymph passes to the hepatic, coeliac and superior mesenteric nodes.

Duodenal Recesses

Small pouches of peritoneum occur in the region of duodenojejunal junction. They are:

- ***Superior and inferior duodenojejunal/mesocolic recesses:*** They are often present. Superior duodenal recess looks downwards and inferior duodenal recess looks upward.
- ***Paraduodenal recess:*** They are present in 20% individuals. Present to the left of duodenojejunal flexure. It is open to the right and upwards.
- ***Retroduodenal recess:*** Occasionaly present behind the third part of duodenum and fourth part.
- ***Mesentericoparietal recess of Waldeyer:*** Present in the first part of mesojejunum, immediately behind the superior mesenteric artery and immediately below the duodenum.

Clinical Correlation

- ***Duodenal ulcers:*** They frequently occur in the first part of the duodenum this being the part most exposed to acid entering from the stomach. (Note that both in the stomach and duodenum ulcers occur in alkaline secreting mucosa). Perforation of an ulcer located on the anterior wall of the duodenum lead to leakage of intestinal contents into the greater sac of peritoneum. The leaked fluid tends to gravitate to the right iliac fossa and can give rise to symptoms resembling those of acute appendicitis. Ulcers on the posterior wall of the first part of the duodenum sometimes erode the gastroduodenal artery resulting in serious haemorrhage.
- The third part of duodenum, lying transversely across the vertebra, is more prone to injury.
- ***Duodenal diverticula:*** Diverticuli can occur in any part of the gut as a congenital anomaly and that these are most common in the duodenum. These tend to arise most commonly in the duodenum near the major duodenal papilla, that is along the medial wall of second part of duodenum. It is usually congenital and solitary. The liver and biliary apparatus, and the pancreas are derived from buds arising in this region. These diverticulae hinder the various interpretations during contrast studies and during various endoscopic procedures. Diverticuli can also be acquired. In congenital diverticuli, all three coats of the gut wall are present, but in acquired diverticuli only the mucosa is present as it herniates out through gaps in the muscle coat. Such herniation is almost always on the mesenteric side of the gut and may be present in relation to points of entry of blood vessels. Acquired diverticuli in the duodenum may be a result of weakening of the wall produced by an ulcer.
- ***Obstruction:*** The duodenum can be obstructed by the ***cystocolic band*** passing from the gallbladder to the transverse colon, by pressure of the superior mesenteric vessel or by an ***annular pancreas*** (which completely surrounds the duodenum).

Jejunum

Other name: Empty intestine.

The jejunum (Latin.jejunus=empty) is in the form of a long coiled tube suspended from the posterior abdominal wall by the mesentery. It is about 4 cms wide and is about 8 feet long, which is the proximal two-fifths of the length from duodenojejunal flexure to ileocaecal junction. The plicae circulares are more pronounced in the jejunum and hence they are seen characteristically in barium meal series. There are no lymphoid aggregates in jejunum.

The coils of both jejunum and ileum occupy the central and lower part of the abdominal cavity, in the interval the ascending colon (on the right) and the descending colon (on the left) (Table 17.1). They are covered anteriorly by the greater omentum, the transverse colon and transverse mesocolon. On the whole the coils of jejunum lie above those of the ileum. The first coil of the jejunum lies in front of the left kidney, behind the transverse mesocolon.

Histology

Small Intestine

Special Features

For adequate absorption of food to take place in it, the small intestine mucosa shows some special features.

Circular folds/plicae circulares/valves of Kerckring: Mucosa and submucosa are thrown into permanent folds which do not disappear on distension. They are numerous in the distal duodenum and jejunum (though they first appear in proximal duodenum) and gradually become less in ileum. They slow the passage of contents and increase the surface area of mucosa. They are named after the 17th century Dutch anatomist Theodor Kerckringius.

Villi: Each Villus is a finger-like projection lined by surface epithelium with the lamina propria projecting into it. The villus contains a core of loose connective tissue, fenestrated blood capillaries and a central blind ended lymphatic vessel called the lacteal. Villi are large and numerous in the duodenum and jejunum, and smaller and fewer in the ileum.

Crypts of Lieberkuhn/intestinal glands: Crypts of Lieberkuhn are tubular invaginations of epithelium into the lamina propria. They open on the luminal surface of intestine at the base of intervillous space. They are named after the 18th century German anatomist Johann Lieberkuhn.

contd...

Table 17.1: Comparison between the jejunum and the ileum

Features	Jejunum	Ileum
Plicae circulares	More pronounced	Few or absent
Peyer's patches	Small and few in number	Large and more in number
Mesentery	Fat is minimum and appear as translucent windows near the vasa recta	Fat present throughout mesentery and translucent windows are absent
Blood supply	One or two rows of long vasa recta	Four or five rows of short vasa recta
Villi	Longer and more numerous	Shorter, less numerous, absent over Peyer's patches

Histology *contd...*

Intestinal glands contains the following types of cells:

- Enterocytes which are tall columnar absorptive cells; each enterocyte contains microvilli at its apical end; the microvilli are seen under light microscope as brush/ striated border. Each microvillus contains a core of actin filaments. Contraction of these filaments make the microvilli to spread apart so that the surface area for absorption is increased. Microvilli possess a specialised glycoprotein coat called glycocalyx which protects the epithelium against pancreatic enzymes in the intestinal lumen.
- Goblet cells which produce mucus; this mucus protects against microorganisms and toxins in the gut lumen, and it also provides lubrication and mechanical protection from the intestinal contents.
- Paneth cells which are found in the deeper parts of the intestinal crypts, particularly in the duodenum. They contain lysosomal enzymes which protect the intestinal luminal surface against bacterial flora. They are named after 19th century German physician Josef Paneth.
- Stem cells which are the source of most of the cell types of the intestinal epithelium.
- Enteroendocrine cells which belong to the APUD cell system. They secrete local hormones such as cholecystokinin, secretin, gastric inhibitory polypeptide(GIP) and motilin. Cholecystokinin and secretin increase the activity of the gallbladder and pancreas and inhibit gastric secretion and motility. Gastric inhibitory polypeptide stimulates the release of insulin in pancreas while motilin stimulates gastric and intestinal motility.

Microfold (M) cells: Microfold (M) cells are epithelial cells overlying the lymphoid aggregates in the intestinal wall. They have broad microfolds on their apical surfaces. They take up antigens from the lumen of intestine by endocytosis and come into contact with cells of the immune system near the deep recess present at their bases and produce antibodies (IgA).

Peyer's patches: Peyer's patches are aggregated lymphoid follicles present in the lamina propria of small intestine especially ileum which protect the gut against invasion of microorganisms. They are named after the 17th century Swiss anatomist Johann Peyer.

Histology

Duodenum

- Mucosa is lined by simple columnar epithelium with microvilli. Few goblet cells are seen. Numerous villi are present. Lamina propria contains crypts of Lieberkuhn which in turn contain columnar cells, goblet cells, Paneth cells and Enteroendocrine cells. Muscularis mucosae is made up of inner circular and outer longitudinal layers. Plicae circulares are seen.
- Submucosa contains Brunner's glands (branched tubulo-acinar glands). Their ducts pass through the muscularis mucosae to open into the bottom of the crypts.

contd...

Histology *contd...*

They secrete thin alkaline mucus to neutralize the acid chyme from stomach and protect the duodenal mucosa from autodigestion.

- Muscularis externa is made up of inner circular and outer longitudinal layers which contain the myenteric nerve plexus in between the two layers of smooth muscle.
- Serosa is the outermost layer that covers the first part of duodenum (peritoneal) while the rest of the duodenum is covered by adventitia.

Jejunum

- Histologic features are the same as in duodenum.
- Mucosa is lined by simple columnar epithelium with microvilli. Prominent intestinal villi and plicae circulares seen.
- Absence of Brunner's glands (after 17th century Swiss anatomist Johann Brunner) and Peyer's patches.

Ileum

- Histologic features are the same as in duodenum.
- Mucosa is lined by simple columnar epithelium with microvilli. Villi are short and few. Lamina propria contains Peyer's patches (aggregated lymphoid follicles). M cells are found overlying the lymphoid follicles. Muscularis mucosae is thin or absent.
- Absence of Brunner's glands in the submucosa.

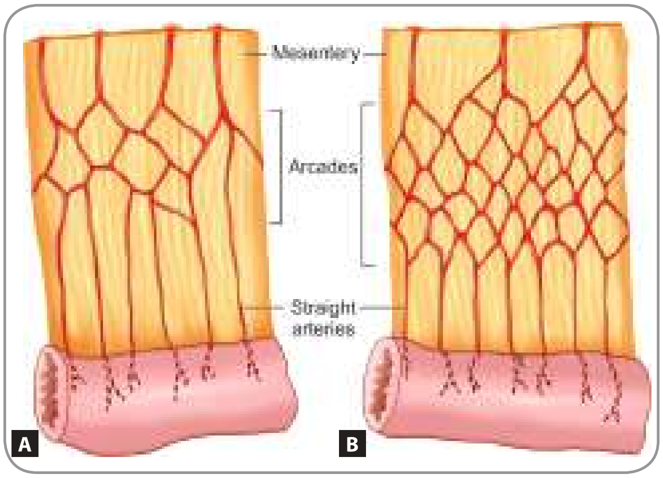
Development

Duodenum

The duodenum develops from the caudal most part of foregut and cranial part of midgut. The junction of the foregut with the midgut is represented by the region of the opening of bile duct in the duodenum. The first part of duodenum and the second part up to the bile duct are developed from the foregut. The second part of duodenum below the opening of bile duct, third and fourth parts are derived from the midgut. The developing duodenum forms a loop, which is attached to the posterior abdominal wall by a mesoduodenum. The loop is present in the sagittal plane, with a ventral convexity, with its apex at the junction of the foregut and midgut. Along with the rotation of stomach, this loop also rotates and falls to the right. The mesoduodenum is absorbed (zygosis) and the duodenum becomes retroperitoneal (secondary retroperitoneal) except for a small part near the pyloric orifice. Due to the differential growth of the duodenal wall, the second part undergoes axial rotation, which permits the head of pancreas to meet the rest of its part. This rotation also establishes connection between the dorsal and ventral pancreatic ducts. At the eighth week of intrauterine development, the lumen of duodenum is obliterated, which recanalises by the end of the third month. Since the duodenum is developed from both foregut and midgut, it receives arterial supply from the coeliac trunk (artery of foregut) and the superior mesenteric artery (artery of midgut).

Jejunum and Ileum

Jejunum and most of the ileum are derived from the prearterial segment of the midgut loop. The terminal portion of ileum is derived from the postarterial segment proximal to the caecal bud.



Figs 17.8A and B: Comparison of the pattern of the arteries supplying the jejunum and the ileum.
Note that the arcades are fewer, and the straight arteries longer, in the jejunum; Fat (yellow) is much more abundant in the mesentery of the ileum

Blood Supply

Jejunum differs from ileum in the mode of blood supply. There are only two or three arterial arcades, hence the vasa recta arising from them are longer when compared to those in ileum. These vasa recta are end arteries and hence are prone to ischaemia. The fat distribution in the mesentery of the jejunum are minimum near the vasa recta and appear as translucent windows within them.

The veins from the jejunum end in the superior mesenteric vein (Figs 17.8A and B).

Lymphatic Drainage

The lymphatic drainage of the jejunum is through nodes present in the mesentery along branches of the superior mesenteric artery. Ultimate drainage is into superior mesenteric nodes.

Ileum

Other name: Twisted intestine.

The ileum (Greek.eilos=coiled or twisted) forms the distal three-fifths of the length from duodenojejunal flexure to ileocaecal junction, which is about 12 feet. The ileum measures about 3.5 cms in width. The mucous membrane of ileum lacks the large transverse folds as these are few or absent. The submucosa of the ileum contains large aggregations of lymphoid tissue that can be seen with the naked eye and are called the ***aggregated lymphatic follicles*** or ***Peyer's patches***. Because of the mobility of the jejunum and ileum, their relations are highly variable (Table 17.1). The terminal part of the ileum lies in the true pelvis. It passes to the right across the right psoas major to join the caecum.

Blood Supply

The ileum receives its blood supply through shorter vasa recta, as the ileal arteries form three or more arcades. When compared to jejunum, the ileum has fat distributed through out the mesentery and hence they lack the translucent windows seen in jejunum. (Figs 17.8 A and B). The veins from the ileum end in the superior mesenteric vein.

Lymphatic Drainage

The lymphatic drainage of the ileum is through nodes present in the mesentery along branches of the superior mesenteric artery and the ileocolic artery, which drain into superior mesenteric nodes.

Clinical Correlation

- ***Barium meal:*** The small intestine can be visualised through the Barium meal series. Jejunum is seen typically as the valves of Kerckring give them a characteristic appearance. The duodenal cap is distorted in duodenal ulcer.
- ***Meckel's diverticulum:*** The persistent remnant of proximal part of vitellointestinal duct is called ***Meckel's diverticulum***. The embryonic gut is connected to the yolk sac through the vitellointestinal duct. Later in foetal life, this duct undergoes complete obliteration and disappearance. However, in some persons its proximal part (near the gut) persists and forms a diverticulum arising from the antimesenteric border of the terminal part of the ileum. The diverticulum is of surgical importance as it may undergo inflammation resulting in symptoms similar to those of appendicitis. The mucosa in the diverticulum can show abnormalities and may have patches of gastric mucosa that can even be the site of a peptic ulcer. It is attached to the ileum about two feet proximal to the ileocaecal junction. Its length is variable and is usually two inches. It is seen in about two percent of the population.
- Persistence of remnants of the vitellointestinal duct can also result in other anomalies as follows:
  - If the entire duct remains patent there is a faecal fistula at the umbilicus.
  - The part of the duct between Meckel's diverticulum and the umbilicus may become a fibrous band. Pressure from such a band may cause intestinal obstruction. It can also cause volvulus.
  - Sometimes the part of the vitellointestinal duct near its junction with the gut disappears, but part of the duct persists near the umbilicus. Such remnants may form:
    - An umbilical sinus.
    - A cyst attached to or embedded in the anterior abdominal wall, or a malignant growth at the umbilicus.

Mesentery

The fold of peritoneum through which coils of jejunum and ileum are suspended from the posterior abdominal wall is called the ***mesentery***. The attachment of the mesentery to the posterior abdominal wall is referred to as the ***root*** of the mesentery (Fig. 17.9). The root is about 15 cm long. When traced towards the gut, the mesentery increases very greatly in length so that it can give attachment to the entire length of the jejunum and ileum (which is about 5 m), hence it is described as fan-shaped.

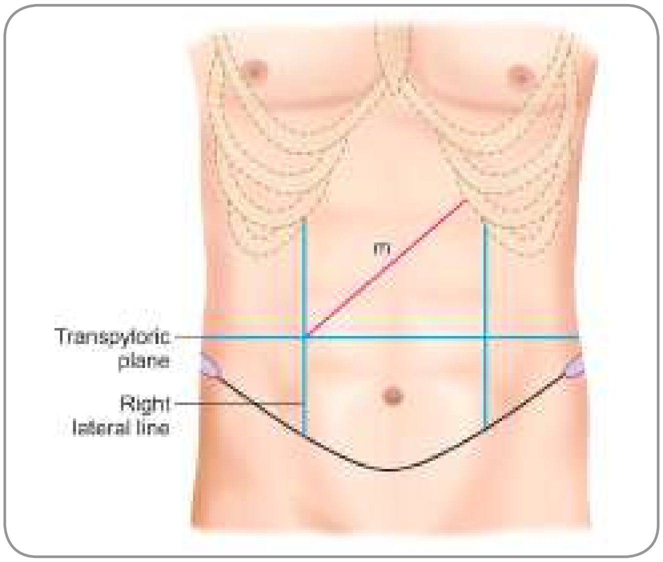


Fig. 17.9: Attachment of root of mesentery (m) to posterior abdominal wall

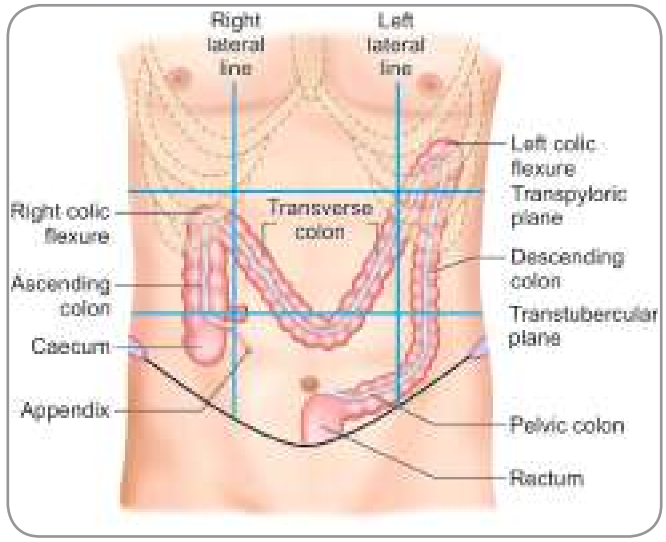


Fig. 17.10: Surface projection of the large intestine. Note that the position of the transverse colon, and of the pelvic (sigmoid) colon is highly variable

The upper end of the root of the mesentery corresponds in position to that of the duodenojejunal flexure. It lies a little to the left of the median plane at the level of the second lumbar vertebra (Fig. 17.9). In relation to the anterior abdominal wall the upper end lies about 3 cm below and medial to the tip of the left ninth costal cartilage. The attachment of the mesentery runs downwards and to the right, its lower end lying to the right of the median plane in front of the right sacroiliac joint. This point corresponds to the junction of the right lateral and intertubercular planes (Fig. 17.9).

The attachment of the root of the mesentery crosses several structures on the posterior abdominal wall. These are:

- The horizontal part of the duodenum
- The abdominal aorta
- The inferior vena cava
- The right psoas major, right genitofemoral nerve

The right ureter and the right testicular (or ovarian) vessels cross behind the root as they descend over the right psoas major.

LARGE INTESTINE

Other name: Intestinum crassum.

The large intestine is about one and a half metres long. The main subdivisions of the large intestine are shown in Figure 17.10. These are the ***caecum,*** the ***ascending colon,*** the ***transverse colon***, the ***descending colon,*** the ***sigmoid*** (***or pelvic***) ***colon***, the ***rectum*** and the ***anal canal***. The large intestine forms a curve within which the small intestine lies. The terminal part of the ileum becomes continuous with the large intestine at the ***ileocaecal junction***. Near this junction the caecum is also joined by a short, narrow, blind tube called the ***vermiform appendix***. The ascending colon meets the transverse colon at the ***right colic flexure***. The junction of the transverse colon with the descending colon is called the ***left colic flexure***.

Histology

Large Intestine

- Mucosa is lined by simple columnar epithelium with plenty of goblet cells. Intestinal villi and plicae circulares are absent. Crypts of Lieberkuhn are numerous and extend through the full thickness of the mucosa. They contain columnar cells, goblet cells and enteroendocrine cells. Paneth cells are absent.
- In muscularis externa, the outer longitudinal layer shows thickening to form three ribbon-like bands called taenia coli. Taenia coli penetrate the inner circular layer at irregular intervals resulting in discontinuities in the muscularis externa which allow parts of colon to contract independently leading to formation of haustrations.
- Serosa shows fat-filled peritoneal pockets called appendices epiploicae.
- Main function is reabsorption of water and electrolytes from and converting the undigested food into faeces.

Vermiform Appendix

- Mucosa is lined by simple columnar epithelium with plenty of goblet cells. Intestinal villi are absent. Crypts of Lieberkuhn are few. Lamina propria contains large number of lymphoid follicles which extend into the submucosa. Muscularis mucosa is disrupted.
- Submucosa is made up of dense irregular connective tissue containing blood vessels, lymphatic vessels and Meissner's plexus.
- Muscularis externa is made up of inner circular and outer longitudinal layers with the myenteric nerve plexus between the two layers.
- Serosa is the outermost layer made up of loose connective tissue covered by peritoneum.

Development

Caecum and Vermiform Appendix

A diverticulum that arises from the postarterial segment of the midgut loop is called the caecal bud. The proximal portion of the bud grows rapidly and forms the caecum. The distal part of the bud remains narrow and forms the appendix. Initially the appendix is seen at the apex of caecum. Later as the medial wall of caecum grows more rapidly than the lateral wall, the point of attachment of the appendix comes to lie on the medial side.

Colon, Rectum and Anal Canal

Ascending colon and the right two-thirds of transverse colon are developed from the postarterial segment of the midgut loop. The left one-third of transverse colon is developed from the hind gut. The dual development of colon is confirmed by its blood supply. The right two-thirds are supplied by the superior mesenteric artery and the left one-third by the inferior mesenteric artery. The descending colon and the sigmoid colon develop from the pre-allantoic part of hind gut. The postallantoic part or endodermal cloaca gives rise to rectum, upper part of anal canal (and most of the mucous lining of the urinary bladder and urethra). The lower part of anal canal is derived from the ectodermal proctodaeum. The line of junction between the endodermal and ectodermal parts of anal canal is represented by the pectinate line.

Peritoneal Relations

The ascending colon and the descending colon are retroperitoneal; they are covered by peritoneum on the front and sides, but posteriorly they are in direct contact with the abdominal wall. The transverse colon is suspended from the posterior abdominal wall by the transverse mesocolon; and the sigmoid colon by the sigmoid mesocolon. The caecum is usually surrounded all round by peritoneum and, therefore, has considerable mobility. The posterior aspect of the caecum is separated from the posterior abdominal wall by a recess of the peritoneal cavity called the ***retrocaecal recess***. The vermiform appendix often lies in this recess. The rectum is partially covered by peritoneum, while the anal canal does not come in contact with peritoneum at all.

Differences Between Small and Large Intestines

The following differences enable a segment of the colon to be easily distinguished from a segment of small intestine (Table 17.2). The colon is much wider than the small intestine. That is why it is called the large intestine. The outer diameter of a segment of small intestine is more or less uniform. In contrast a segment of the colon (Fig. 17.11) shows a series of ***sacculations*** (also called ***haustrations***). In the case of the small intestine, the layer of longitudinal muscle is of uniform thickness all round its circumference. In the caecum and colon, however, the longitudinal muscle layer shows thickenings at three places on the circumference. These thickenings of muscle form three prominent bands that run along the length of the colon, approximately equidistant from each other. These bands are called the ***taenia coli***. The taenia coli appear to be shorter than the rest of the wall of the colon (Fig. 17.11). This may be one reason for presence of sacculations in the wall of the colon. Attached to the outer wall of the colon there are numerous irregular projections called the ***appendices epiploicae***. Each of these consists of a small mass of fat enclosed by a covering of peritoneum.

Table 17.2: Comparison between the small and the large intestines (Fig. 17.12A and B)

Features	Small intestine	Large intestine
Lumen	narrow	Wide
Sacculations	absent	Present
Taenia coli	absent	Present
Appendices epiploicae	absent	Present

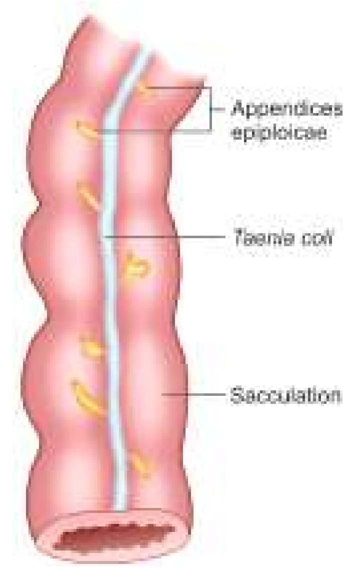


Fig. 17.11: A segment of the colon

Caecum

Other name: Blind gut, typhlon, cul-de-sac of the gut.

The terminal ileum joins the large intestine in the right iliac fossa. The part of the large intestine lying (here) below the level of the ileocaecal junction is called the ***caecum***. It is so called as its lower end is blind (Latin.caecus=blind). Superiorly, the caecum is in open communication with the ascending colon. The caecum is about 6 cm in length, and about 7.5 cm in width. (The width is greater than the length). In relation to the anterior abdominal wall the caecum lies in a triangle bounded above by the transtubercular plane, medially by the right lateral line and below and laterally by the inguinal ligament (Fig. 17.10). The ileocaecal junction lies at the intersection of the right lateral and transtubercular planes. The vermiform appendix opens into the caecum about 2 cm below this point. The orifice is guarded by a fold of mucous membrane called as valve of Gerlach.

Shape

The caecum is usually asymmetrical and may have different shapes. It may be:

- Conical with the appendix arising from the apex (foetal type) or
- Quadrate (infantile type) or
- Asymmetrical with the right aspect lower than the left (adult type) or
- Enlarged very much on the right side (Exaggerated type).

Relations

The caecum is surrounded all round by peritoneum and is related anteriorly to the anterior abdominal wall and posteriorly to the vermiform appendix which frequently lies in the retrocaecal recess. Behind this recess the caecum rests on the right iliacus and psoas major muscles. The lateral cutaneous nerve of the thigh intervenes between the iliacus and the caecum.

Blood Supply

The caecum is supplied by the anterior and posterior caecal branches of inferior division of ileocolic artery of superior mesenteric artery.

The veins drain into ileocolic vein and further into superior mesenteric vein.

Nerve Supply

The sympathetic supply is from superior mesenteric plexus (T10–L1) and parasympathetic is via the vagus nerve.

Lymphatic Drainage of Caecum

Lymph passes through ileocolic nodes to superior mesenteric nodes.

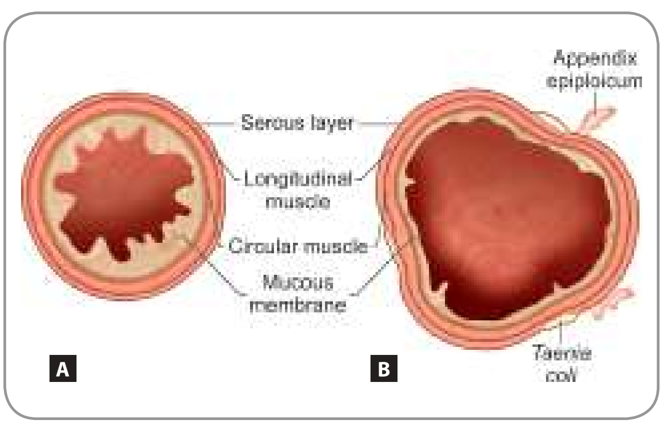
Ileocaecal Junction

The ileum enters the posteromedial aspect of the large intestine. The junction marks the plane of demarcation between the caecum and the ascending colon. A valvular or sphincteric function is often ascribed to the junction, although this is not supported by physiological evidence. When viewed after opening the caecum (Fig. 17.13) the junction presents a transverse slit about 2.5 cms long, bounded by upper and lower lips. At the edges of the slit the lips fuse with each other and become continuous with folds of mucous membrane called the ***frenula.*** The wall of the ileum projects for some distance into the cavity of the large intestine. It is this projection that is responsible for the formation of prominent upper and lower lips of the ileocaecal orifice. It prevents the regurgitation of caecal contents back into the ileum.

Vermiform Appendix

Other names: Appendix caeci, Vermiform process, Appendix vermiformis.

The vermiform appendix (Latin.vermis=worm) looks very much like a round worm—hence the name vermiform. It is a tube only a few millimetres wide, and about 9 cm in length. The length is, however, highly variable being anything between 2 to 20 cm. It has a base,



Figs 17.12A and B: Transverse sections through the **A.** Small intestine and **B.** Large intestine to show differences in basic structure

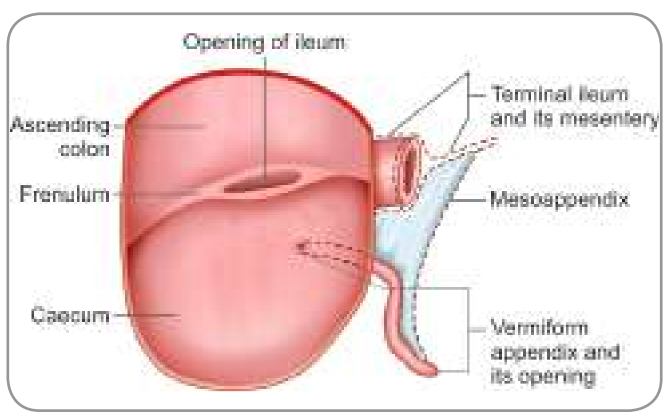


Fig. 17.13: Features in the interior of caecum seen after opening it

tip and a body. The ***base*** opens into the (posteromedial part of the) caecum, where all the three taeniae converge. The taenia in front of the caecum is, therefore, a useful guide in locating the appendix.

The ***tip*** is the free blunt end of the appendix. The opening into the caecum lies about 2 cm below the opening of the ileum. At this opening, a fold of mucous membrane may be present. This fold simulates a valve and is called the valve of Gerlach.

The appendix has a short mesentery called the ***mesoappendix***. Unlike other mesenteries, the mesoappendix is not attached to the posterior abdominal wall, but to the mesentery of the terminal part of the ileum (Fig. 17.13).

The appendix is mobile and highly variable in position (Fig. 17.14A to E). In about 60 percent of individuals it lies behind the caecum, in the retrocaecal recess of the peritoneal cavity where part of it may lie behind the lower end of the ascending colon (retrocaecal position). In about 30 percent of individuals the appendix extends downwards and medially into the true pelvis (pelvic position). In this case, the appendix crosses the right external iliac artery. In the female, it may lie close to the right ovary and uterine tube. The appendix may be inferior to the caecum and the tip ascends to the side of caecum (subcaecal and paracolic position). The appendix may be (preileal position) in front of the terminal ileum or (postileal position) behind the terminal ileum (Figs 17.14A to E). The tip of the appendix may be directly facing downwards in rare instances (Mid–inguinal position).

Blood Supply

The appendix is supplied by a branch of the ileocolic artery from the superior mesenteric artery. This artery runs in the mesoappendix. However, over the distal part of the appendix the mesoappendix becomes very short and the artery may come into direct contact with the wall of the appendix. The vein accompanies the artery and ultimately drains into the superior mesenteric vein.

Nerve Supply

The sympathetic innervation is from the superior mesenteric plexus (T10) and the parasympathetic innervation is from the vagus nerve.

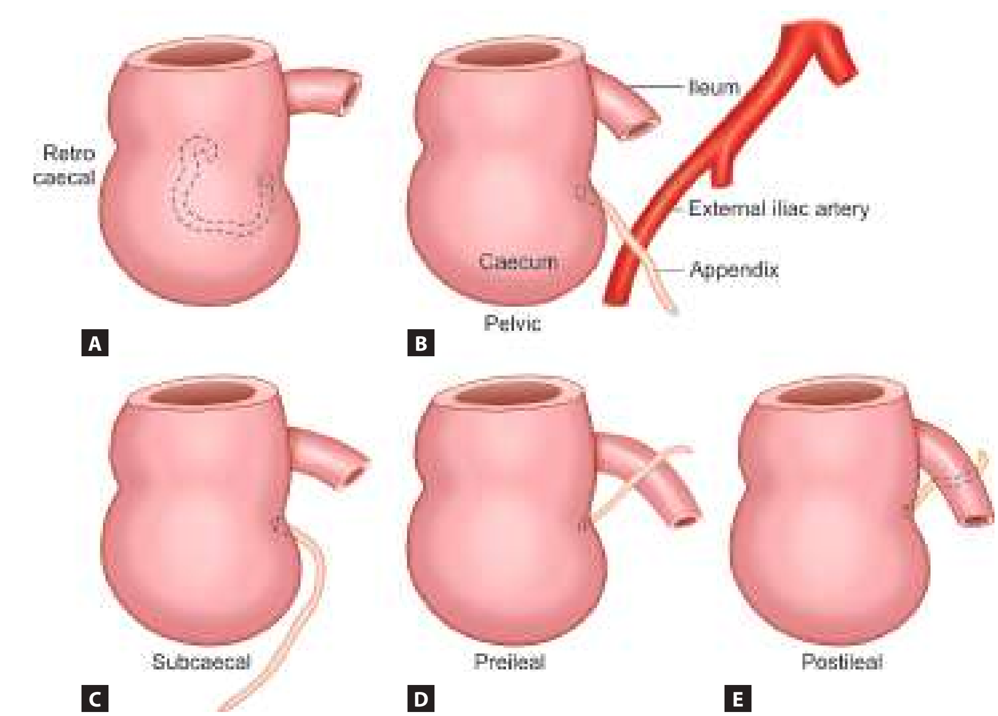
Lymphatic Drainage

Lymph from the appendix drains through the ileocolic nodes into the superior mesenteric nodes.

Surface Marking

The base of the appendix can be projected on the anterior abdominal wall.

The anterior superior iliac spine and the umbilicus are first joined by a straight line. A point is marked at the junction of the lateral and middle thirds of this line. This point marks the base of the appendix. This is referred to as the ***Mc Burney's point***.



Figs 17.14A to E: Various positions of the vermiform appendix

Clinical Correlation

In appendicectomy, the skin incision passes through this point, at right angle to the line mentioned above (***Mc Burney's incision***).

- ***Appendicitis:*** Inflammation of the appendix is ***appendicitis.*** The basic structure of the appendix is similar to that of the large intestine (Fig. 17.12B). The submucosa contains large amounts of lymphoid tissue that pushes the mucosa towards the lumen and narrows the latter. This might lead on to acute appendicitis followed by suppuration and appendicular abscess.
- ***Referred pain:*** Pain of appendicitis is first felt around the umbilicus. This referred pain is due to the innervation of appendix (T10), which is same as the dermatome of the umbilicus. It is vaguely localised, and of relatively low intensity. When inflammation reaches the parietal peritoneum pain shifts to the right iliac fossa. Here, the pain is precisely localised and severe.
- ***Position of appendix and pain:*** Variations in position of the appendix have been mentioned above. The position can influence symptoms observed in appendicitis. If the appendix is retrocaecal (as it very often is) tenderness may be difficult to elicit over the right iliac fossa, specially if the caecum is distended with gas. Such an appendix comes into contact with the psoas major muscle. Because of this, pain may be felt on extending the right hip joint (the muscle being stretched in this position). So, the patient tends to keep the right thigh flexed.

  When the appendix is in the pelvic position tenderness may be present in the hypogastrium instead of the right iliac fossa. Tenderness may also be elicited by rectal or vaginal examination. A pelvic appendix may irritate the obturator internus muscle, and the patient may find relief in keeping the hip laterally rotated. Flexion and internal rotation of the right hip joint (which causes the obturator internus to be stretched) may produce pain in the hypogastrium.

  In incomplete descent of the caecum the appendix may be subhepatic and appendicitis may be confused with cholecystitis.
- ***Complications of appendicitis:*** When the appendix is inflamed (***appendicitis***) infection may spread to the artery resulting in thrombosis. If this happens the distal part of the appendix undergoes necrosis, with danger of its bursting. Rupture of the appendix is a very serious complication of appendicitis as infection then spreads to the peritoneum (***peritonitis***).
- Apart from appendicitis other conditions that may affect the appendix are malignant growths, the appendix being the most common site for a carcinoid tumour and diverticulosis.

Colon

The part of large intestine from the caecum to the rectum is called the colon (Greek.kolon=food or meat). According to position, the colon is divided into the following parts: ascending colon, transverse colon, descending colon and sigmoid colon.

Ascending Colon

Other name: Colon ascendens.

The ascending colon lies vertically in the right lateral region of the abdomen. It is about 15 cm long.

Its lower end is continuous with the caecum at the level of the intertubercular plane. Its upper end meets the transverse colon at the right colic flexure. This flexure lies about an inch below the transpyloric plane (to the right of the right lateral line). The ascending colon is covered by peritoneum in front and on either side, but posteriorly it is in direct contact with structures on the posterior abdominal wall. Its lowermost part may be separated from this wall by an upward extension of the retrocaecal recess. Rarely, the ascending colon may have a short mesocolon. It is then covered all round by peritoneum.

Relations

The posterior relations of the ascending colon are as follows:

- Its lower part rests on the iliacus muscle
- Just above this muscle it rests on the iliac crest
- Above the iliac crest, it lies on the quadratus lumborum (medially) and the transversus abdominis (laterally).
- The lateral cutaneous nerve of the thigh, and the iliac branch of the iliolumbar artery intervene between the colon and the iliacus.
- The quadratus lumborum and transversus abdominis are partly separated from the colon by the lower part of the right kidney, and by the iliohypogastric and ilioinguinal nerves.

Anteriorly, the ascending colon is in contact with anterior abdominal wall.

Its upper end (right colic flexure) lies deep to the liver, and just to the right of the duodenum and gallbladder.

Blood Supply

The ascending colon is supplied by the marginal artery, formed by the anastomoses of ileo colic and right colic branches of superior mesenteric artery. The lower one-third of the ascending colon is supplied by the ileocolic branch and the right colic branch supplies the upper two-thirds of ascending colon.

Corresponding veins drain into the superior mesenteric vein.

Transverse Colon

Other name: Colon transversum.

The transverse colon is the longest subdivision of the large intestine. It begins at the right colic flexure (which lies in the right lateral region a short distance below the transpyloric plane). It ends at the left colic flexure. The left colic flexure is distinctly higher than the right flexure, and extends above the transpyloric plane into the left hypochondrium (Fig. 17.10).

Between the right and left colic flexures, the transverse colon forms a downward loop of varying size. Its lowest part frequently descends to a level below the umbilicus and may even descend into the pelvis. Its total length is about 50 cm (Fig. 17.15).

Relations

Anteriorly, the transverse colon is overlapped by the greater omentum which separates it from the anterior abdominal wall. Posteriorly, its right end crosses in front of the descending part of the duodenum and the pancreas. The rest of it lies in front of coils of jejunum and ileum. Along its upper margin, the transverse colon lies close to (or in contact with) the liver, the gallbladder, stomach and spleen. At its left extremity (i.e., the left colic flexure), it lies just below the spleen and the tail of the pancreas. The left kidney lies immediately medial to the left colic flexure.

Blood Supply

The right two-thirds of the transverse colon are supplied by the branches of the superior mesenteric artery, namely, the middle colic branch. The left one-third of the transverse colon is supplied by left colic branch of the inferior mesenteric artery. Here too, the anastomoses exists as the marginal artery. This dual source of blood supply is in concordance with the development of transverse colon, which is from both the midgut and hindgut.

Corresponding veins drain both into the superior as well as the inferior mesenteric veins.

Nerve Supply

The superior mesenteric plexus (T12–L1) and the vagus nerves supply the sympathetic and parasympathetic innervation to the right two-thirds of the transverse colon. The left one-third receive sympathetic supply from superior hypogastric plexus (L1-L2) and parasympathetic from pelvic splanchnic nerves (S2-S4).

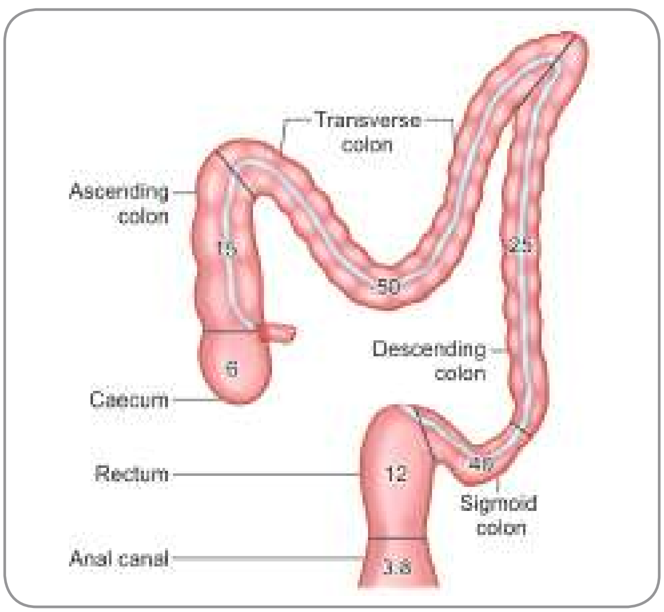


Fig. 17.15: Scheme to show the lengths (cm) of the various subdivisions of the large intestine. The coils of sigmoid colon are not drawn

Lymphatic Drainage

The lymph from the right two-thirds drain into the superior mesenteric nodes and those from the left one-third drain into the inferior mesenteric nodes

Transverse Mesocolon

The transverse colon is attached to the posterior abdominal wall through the transverse mesocolon.

The attachment of this mesocolon to the posterior abdominal wall is transverse. It is attached to the anterior aspect of the head of the pancreas and to the anterior border of the body of the pancreas. The greater omentum and transverse mesocolon are attached to the posterior abdominal wall parallel to each other, the attachment of the greater omentum being superior.

On reaching the posterior abdominal wall, the posterior layer of the greater omentum is immediately reflected off again to form the anterior layer of the transverse mesocolon. It may, therefore, appear that the greater omentum is attached to the transverse colon (Fig. 17.16). However, the two can be easily separated from each other.

Descending Colon

Other name: Colon descendens.

The descending colon begins at the left colic flexure. Its upper end, therefore, lies in the left hypochondrium a little above the transpyloric plane. From here the descending colon descends through the left lateral region, and the left inguinal region to reach the left side of the brim of the true pelvis (just above the inguinal ligament). It ends here by becoming continuous with the sigmoid colon.

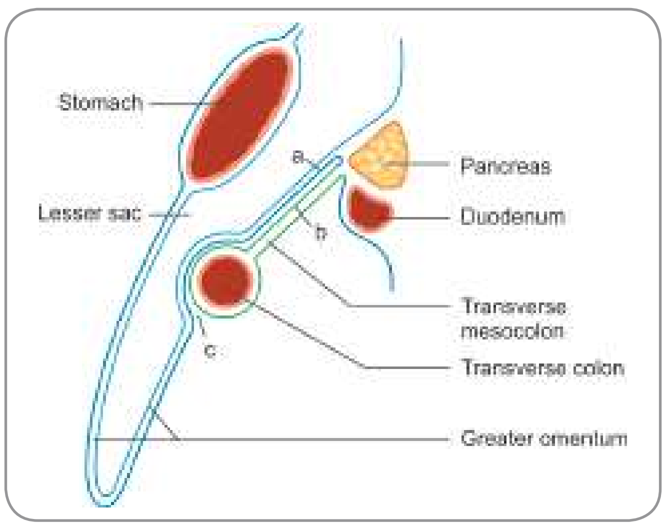


Fig. 17.16: Scheme to show the relationship of the transverse mesocolon to the greater omentum

Key: a. 4th layer of greater omentum **b.** Anterior layer of transverse mesocolon **c.** Cleavage plane that can be obtained between the two layers

The descending colon is retroperitoneal and, therefore, has very limited mobility. It is covered by peritoneum on the front and sides, but posteriorly it rests directly on the abdominal wall. Rarely, however, it may have a short mesocolon. The upper end of the descending colon (i.e., the left colic flexure) is anchored to the diaphragm by a fold of peritoneum called the ***phrenicocolic ligament***. The descending colon is about 25 cm in length.

Relations

The posterior relations of the descending colon are as follows:

- The left kidney (lower lateral part)
- The left transversus abdominis
- The left quadratus lumborum
- The left iliacus
- The left psoas major muscle.

Smaller structures deep to the descending colon are similar to those related to the ascending colon and caecum on the right side. They include:

- The left iliohypogastric nerve
- The left llioinguinal nerves
- The left lateral cutaneous nerve of the thigh
- The left iliac branch of the iliolumbar artery.

Just above the inguinal ligament, the descending colon lies over the external iliac artery, the femoral nerve, the genitofemoral nerve and the testicular vessels (in the male). Anteriorly, the descending colon is related to the anterior abdominal wall, but in its upper part, coils of jejunum may intervene between it and this wall.

Blood Supply

The descending colon is supplied by the left colic and the sigmoid branches of the inferior mesenteric artery.

Corresponding veins drain into the inferior mesenteric vein.

Sigmoid Colon

Other names: Colon sigmoideum, colon pelvicum.

The sigmoid, or pelvic, colon (Greek.sigma=the letter S, eidos=resembling) is highly variable in length, but is usually about 40 cm long. It is continuous at one end with the lower end of the descending colon, and at the other end with the rectum at the level of S3 vertebra. The junction with the descending colon lies over the pelvic brim (left half). The junction with the rectum is more or less in the median plane. Between these ends, the sigmoid colon forms a convoluted loop that is enclosed all round by peritoneum and is attached to the posterior abdominal wall by the sigmoid mesocolon (see below).

Relations

Being located in the true pelvis the sigmoid colon is related to structures on its wall (particularly on the left side) as well as to viscera. The structures on the pelvic wall include:

- The internal and external iliac vessels.
- The obturator nerve, the ductus deferens (in the male).
- The ovary (in the female).

A part of the sigmoid colon frequently lies between the rectum and the urinary bladder in the male and between the rectum and the uterus in the female.

Sigmoid Mesocolon

The line of the attachment of the sigmoid mesocolon to the posterior abdominal and pelvic walls is shaped like an inverted 'V'. The apex of the 'V' overlies the bifurcation of the left common iliac artery. The left ureter crosses the artery just deep to the apex of the mesocolon. The left limb of the 'V' runs downwards along the external iliac artery, on the medial side of the psoas major, to reach the junction of the sigmoid colon with the descending colon. The right limb of the 'V' runs downwards and medially over the pelvic wall to reach the junction of the sigmoid colon with the rectum, in the median plane.

Clinical Correlation

- ***Intestinal Obstruction:*** It may be acute or chronic. Acute intestinal obstruction is a surgical emergency. Congenital causes of obstruction include:
  - Obstruction caused by non-development of nerve plexuses over a length of the gut wall leading to interference with peristalsis and with passage of contents through the affected part. This has been observed most typically in the distal part of the colon. The part of the colon proximal to the defect becomes dilated with intestinal contents and becomes large. The condition is called ***megacolon*** or ***Hirschsprung's disease***. Surgical treatment of the condition involves resection of the aganglionic segment.
  - Obstruction caused by external pressure from abnormal peritoneal bands, or blood vessels.
- ***Errors of rotation and fixation:*** The normal location of various parts of the gut within the abdomen depends on orderly rotation of the gut during development. Abnormalities in rotation can lead to various anomalies. The small intestine (which normally occupies mainly the lower left part of the abdominal cavity) may lie on the right side, and the entire large intestine may lie towards the left. Normally, the transverse colon lies in front of the superior mesenteric vessels, while the duodenum lies behind them. The arrangement may be reversed. The caecum and appendix may lie just below the liver (***subhepatic caecum***), or may descend only to the lumbar region. All organs in the abdomen may show side to side reversal (***situs inversus***).
  A part of the gut that normally has a mesentery (and is mobile) may be fixed; and conversely a part that is normally fixed may become mobile. Abnormal mobility may result in twisting of the intestine leading to obstruction to blood supply. The condition is called ***volvulus***.
- ***Diverticulosis:*** Diverticuli can occur in any part of the gut as a congenital anomaly. Diverticuli of colon are usually seen as rows. These can be sites of infection, and, occasionally, of perforation.

contd...

Clinical Correlation ***contd…***

- ***Neoplasms of the intestines:*** Neoplasms may be benign or malignant. They are seen much more commonly in the colon than in the small intestine. Within the small intestine, carcinoma is more frequent in the jejunum than in the ileum. Cancers of the colon are usually slow growing, and if recognised in time they can be removed completely. Histologically, the neoplasms can be of various types. A relatively uncommon type is a ***carcinoid tumour*** arising from argentaffin cells. Such tumours secrete large amounts of 5-hydroxytryptamine. In surgery for removal of a carcinoma of the colon, it has to be remembered that lymphatic drainage takes place alongside blood vessels. Hence, it may be necessary to ligate and remove a large artery to the region. The entire area of gut supplied by that artery has to be removed.
- ***Strangulation in hernias:*** Coils of intestine can be constricted at the neck of the sac of a hernia and can undergo obstruction and strangulation. An internal hernia can also be a cause for obstruction. Internal herniae can occur into:
  - The aditus to the lesser sac
  - A defect in the mesentery
  - A defect in the transverse mesocolon
  - A defect in the broad ligament
  - One of the peritoneal recesses around the duodenum or the caecum.
- ***Intussusception:*** This term is used for a condition in which one part of gut invaginates into another part leading to obstruction.
- ***Volvulus:*** This condition results if a loop of gut rotates on itself. Such rotation may take place around a fibrous band. Volvulus may occur in the ileum, the caecum, or the pelvic colon.
- ***Bands and adhesions:*** Pressure from peritoneal adhesions, or fibrous bands can lead to intestinal obstruction. The bands may be congenital (discussed above) or may be formed following peritonitis.
- ***Strictures:*** Strictures of the small intestine can follow ulceration e.g., in tuberculosis. They can lead to intestinal obstruction.
- ***Paralytic ileus:*** In this condition, there is no physical cause of obstruction. The condition is due to a failure of the neuromuscular mechanism governing peristalsis. The condition may occur after an abdominal operation, or after peritonitis.
- ***Embolism and thrombosis in blood vessels:*** Embolism in an artery, or thrombosis in a vein supplying a part of a gut leads to loss of blood supply. There is infarction of tissue that leads to swelling and obstruction.

INNERVATION OF THE GUT

The gut is innervated by sympathetic and parasympathetic (vagal) nerve fibres. The distribution of the vagus nerve in the abdomen is described below. The abdominal part of the sympathetic trunk is described in Chapter 25.

Vagus Nerve in the Abdomen

The fibres of the right and left vagus nerves emerge from the posterior pulmonary plexuses (within the thorax) and descend on the oesophagus forming an ***anterior*** and a ***posterior oesophageal plexus.***

Although both plexuses receive fibres from the nerves of both sides the anterior plexus is formed mainly by fibres from the left vagus and the posterior plexus mainly by fibres from the right vagus. Fibres emerging from the lower end of the anterior oesophageal plexus collect to form the ***anterior vagal trunk*** which is made up mainly of fibres from the left vagus. Similarly, fibres arising from the posterior oesophageal plexus (mainly right vagus) collect to form the ***posterior vagal trunk.*** The anterior and posterior vagal trunks enter the abdomen through the oesophageal opening in the diaphragm and are distributed as follows:

- The ***anterior vagal trunk*** supplies:
  - The anterosuperior surface of the stomach.
  - The superior and descending parts of the duodenum.
  - The head of the pancreas and the liver.
- The ***posterior vagal trunk*** supplies:
  - The posteroinferior surface of the stomach.
  - The posterior vagal trunk gives a large ***coeliac branch*** which ends in the ***coeliac plexus***. This plexus surrounds the coeliac trunk and stretches between the right and left ***coeliac ganglia*** (which lie on the corresponding crus of the diaphragm).

Fibres from the coeliac plexus pass into several secondary plexuses that surround branches of the abdominal aorta. These are the splenic, hepatic, renal, suprarenal and superior mesenteric plexuses. Fibres passing through these plexuses provide parasympathetic innervation to the whole of the small intestine, the large intestine up to the junction of the right two-thirds and left one-third of the transverse colon, the liver, the kidneys, and the spleen. It may be noted that all these plexuses also receive numerous sympathetic fibres and that many fibres in them are afferent.

As a rule, parasympathetic nerves stimulate intestinal movement and inhibit the sphincters. They are also secretomotor to the glands in the mucosa. Sympathetic fibres are distributed chiefly to blood vessels. The parasympathetic nerve supply to the greater part of the gastrointestinal tract (from pharynx to the right two-thirds of the transverse colon) is through the vagus. The left one-third of the transverse colon, the descending colon, the sigmoid colon, the rectum and the upper part of the anal canal are supplied by the sacral part of the parasympathetic system.

Sympathetic Innervation

The preganglionic sympathetic neurons for the gut are located in the thoracolumbar region of the spinal cord. Their axons pass through the sympathetic trunk without relay. They travel through the splanchnic nerves to terminate in plexuses (or ganglia) related to the coeliac trunk, the superior mesenteric artery, the inferior mesenteric artery and the aorta itself. Postganglionic neurons are located in these plexuses. Another set of preganglionic neurons concerned are located in segments S2, S3 and S4 of the spinal cord. They emerge through the ventral nerve roots of the corresponding nerves, and pass into their ***pelvic splanchnic branches***. The fibres to the rectum and the upper part of the anal canal pass through the ***inferior hypogastric plexus***. The remaining fibres pass through the ***superior hypogastric plexus*** and are distributed along the inferior mesenteric artery. The postganglionic parasympathetic neurons are located in the myenteric and submucosal plexuses in the region to be supplied and reach via vagus nerve. Afferent fibres from the gut travel along both sympathetic and parasympathetic pathways. Those from the rectum and lower part of the pelvic colon are carried by the pelvic splanchnic nerves.

INVESTIGATION OF THE GUT

Several kinds of investigations may be required to diagnose diseases affecting different parts of the gut. Any radiological procedure in the abdomen should be preceded by careful preparation of the patient. The objective of preparation is to remove gas and faecal matter from the intestines as they cast shadows that may obscure significant findings. This is achieved by restricting feeding for some hours, and by the use of laxatives and substances that absorb gas (e.g., charcoal tablets).

- ***Plain skiagram:*** A plain skiagram shows shadows of bones in the region. Some soft tissues also cast faint shadows.
  - The domes of the diaphragm can be made out
  - The psoas major muscle, the kidneys, the liver and the spleen may cast light shadows
  - Swallowed air present in the fundus of the stomach is usually seen under the left dome of the diaphragm (fundal gas shadow).
- ***Barium meal:*** Skiagrams taken after administering a barium meal (barium sulphate suspension) can reveal many details about the mucosa of the stomach, the duodenum and the small intestine.
  - The pattern of mucosal folds in the stomach can be seen.
  - Barium filling the first part of the duodenum casts a characteristic shadow that is referred to as the ***duodenal cap***.
  - Mucosal folds in the distal part of the duodenum and in the jejunum produce a feathery appearance.
  - The large intestine shows characteristic haustrations
- ***Barium enema:*** A barium sulphate suspension can be introduced into the large intestine through the anus. The large intestine is much better visualised than with a barium meal.
- ***Newer imaging techniques:*** Investigation of the abdomen (and other parts of the body) has been revolutionised in the recent years by the introduction of several new techniques. The following are now in common use:
  - ***Ultrasonography:*** The principle of the method is that ultrasound waves applied to any part of the body are reflected back by various structures. The reflected waves can be picked up and visualised on a screen. Images of internal organs can be obtained in this way.
  - ***Computed tomography:*** The term tomography has been applied to radiological methods in which tissues lying in a particular plane are visualised. In this technique, images at a series of levels are analysed using computers. Such analysis provides images giving a remarkable degree of detail.
  - ***Magnetic resonance imaging:*** This is a complex technique in which, strong magnetic fields, and radio pulses are used to create images of outstanding clarity. The images are distinctly superior to those of CT scans. Using MRI, sectional appearances in sagittal, coronal and transverse planes can be obtained. The ability to image structures in multiple planes makes spatial localisation and differentiation of lesions more accurate. In additional to sectional images in different planes three dimensional pictures can also be produced (by combining information from a series of sectional views). The main advantages of MRI are high contrast, good soft tissue discrimination, absence of bone and metal artefacts, and the use of non-ionizing radiation. However, like all other techniques, MRI has its limitations. It is of high cost and requires long time in that the patient being investigated has to be confined within a tube for a prolonged period (during which there can be difficulty in monitoring a critically ill patient). Obese persons or those with metallic implants or pacemakers cannot be subjected to this technique.
- ***Endoscopic examination:*** The interior of many parts of the gut can be viewed directly through endoscopic instruments. The range has been greatly extended by the development of flexible instruments. These include oesophagoscopy, gastroscopy, sigmoidoscopy and colonoscopy.

Added Information

Most parts of the digestive tract have been named after their appearances during anatomical studies. The jejunum has been so named (empty) because it always appeared empty during cadaveric dissection studies (and very often during surgical procedures too). The ileum (coiled) has been called so because of its coiled appearance as the abdominal cavity is opened. The caecum (blind) appears as a blind dilated pouch. Its other name is typhlon which also is derived from the Greek term for blind (typhlos). The appendix has been named after its resemblance to a small worm hanging from the caecum.

In earlier times, the lower part of stomach was generally called the ***pylorus***. Later workers confined the term to the pyloric sphincter area to which the name is better suited (gate keeper).

Development

Rotation of Gut

With the superior mesenteric artery as the axis, the midgut having two segments, namely the prearterial segment (proximal segment) and the postarterial segment (distal segment), undergoes rotation. The prearterial segment being cranial and the postarterial segment being caudal, after a 90° anticlockwise rotation, the prearterial is on the right and the postarterial is on the left. As the prearterial segment elongates and forms the small intestine, the coils on their return to the abdominal cavity undergo another 90° anticlockwise rotation, so that the postarterial segment is now cranial and the prearterial segment is caudal. The coils of small intestine pass posterior to the superior mesenteric artery and occupy the posterior and central position of the abdominal cavity. As the postarterial segment returns to the abdominal cavity, the gut loop undergoes the third 90° rotation (a total of 270°). The caecum and appendix lie on the right side below the liver. As the caecum descends to the right iliac fossa, the ascending, transverse and descending parts of colon become distinct.

Multiple Choice Questions

1. The stomach bed is formed by all the following structures except:
   a. Splenic artery
   b. Transverse mesocolon
   c. Right kidney
   d. Anterior surface of pancreas

2. McBurney's point lies at the junction of .... on an imaginary line between the umbilicus and the anterior superior iliac spine.
   a. Medial two-thirds and lateral one-third on left side
   b. Medial two-thirds and lateral one-third on right side
   c. Medial one-third and lateral two-thirds on left side
   d. Medial one-third and lateral two-thirds on right side

3. The distance of major duodenal papilla from pyloric orifice is:
   a. 4 – 6 cm
   b. 6 – 8 cm
   c. 8 – 10 cm
   d. 10 – 12 cm

4. The inferior pancreaticoduodenal artery arises from the:
   a. Superior mesenteric artery
   b. Inferior mesenteric artery
   c. Gastroduodenal artery
   d. Right gastric artery

5. Root of mesentery crosses the following structures except:
   a. Abdominal aorta
   b. Inferior vena cava
   c. Right ureter
   d. Left ureter

ANSWERS

1. c **2.** b **3.** c **4.** a **5.** d

Clinical Problem-solving

Case Study 1: A 27-year-old man complained of pain around the umbilicus for two days. Then his pain shifted to the right iliac fossa and became severe.

- What is your suspicion about the condition?
- How is the location/position of the organ related to the pain?
- What is the relationship of McBurney's point to this condition?

Case Study 2: A 36-year-old woman has been advocated to have arium meal radiography by her gastroenterologist.

- What is the most probable condition?
- In what way will arium meal radiography help?

(For solutions see Appendix).

Chapter 18

Viscera of Digestive Tract—II: Liver, Pancreas and Spleen

Frequently Asked Questions

- Discuss in detail about the liver and its peritoneal relations.
- Discuss in detail about the extrahepatic biliary apparatus.
- Discuss the pancreas in detail.
- Write briefly on: (a) Ligaments of liver, (b) Visceral surface of liver, (c) Common bile duct, (d) Spleen.

LIVER

Other names: Hepar, jecur.

The liver is one of the largest organs in the body weighing about 1.5 kg. It is by far the largest gland. It is included amongst the accessory organs of the alimentary system because it produces a secretion, the bile, which is poured into the duodenum (through the bile duct) and assists in the digestive process. All the blood circulating through the capillary bed of the abdominal part of the alimentary canal (excepting the lower part of the anal canal) reaches the liver through the portal vein and its tributaries. In this way, all substances absorbed into the blood from the stomach and intestines are filtered through the liver, where some of them are stored and some toxic substances may be destroyed. Numerous other functions essential to the well being of the individual are performed in the liver that is, therefore, regarded as one of the vital organs.

The liver lies in the upper, right part of the abdominal cavity (Fig. 18.1). It lies mainly in the right hypochondrium and in the epigastrium, but part of it extends into the left hypochondrium as far as the left lateral line and part of it into the right lateral region. When seen from the front (Fig. 18.1) the liver is roughly triangular and appears to have upper, lower and right borders. In the midline, the upper border lies at the level of the xiphisternal joint. To the right of the midline, the upper border follows the upward convexity of

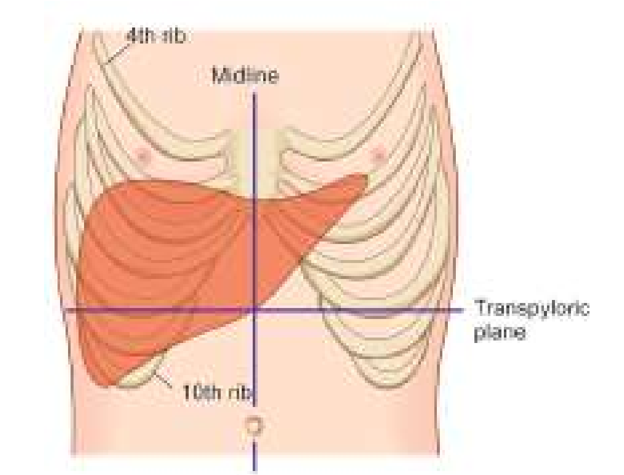


Fig. 18.1: Surface projection of the liver as seen from the front

the right dome of the diaphragm reaching to a level just below the right nipple. To the left of the midline, the upper border follows the curve of the medial part of the left dome of the diaphragm, and ends a little below and medial to the left nipple. The right border runs vertically, with an outward convexity and ends at the level of the tip of the tenth costal cartilage. The lower border runs obliquely upwards and to the left. It crosses the midline at the level of the transpyloric plane. Most of the liver is placed deep to the costal margin and comes into contact with the anterior abdominal wall in the epigastrium. A liver extending below the level of the lateral part of the right costal margin is considered to be enlarged.

Before proceeding to study the features of the individual surfaces of the liver, it is necessary to briefly consider the basic peritoneal relationships of the organ with regard to its development. At an early stage in development, the stomach has a ventral mesogastrium that passes

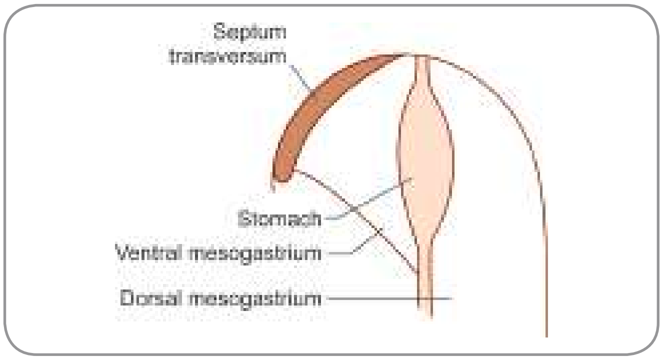


Fig. 18.2: Ventral and dorsal mesogastria as seen from the left side

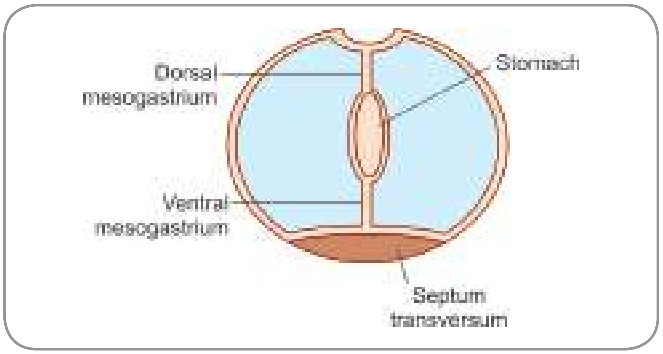


Fig. 18.3: Ventral and dorsal mesogastria as seen in transverse section

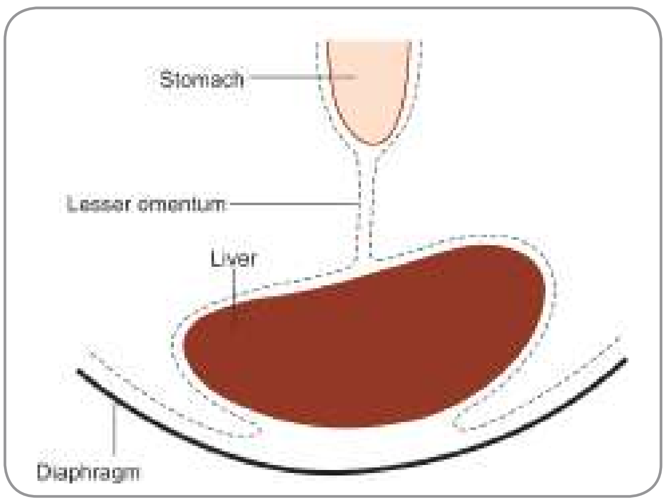


Fig. 18.4: Transverse section at a later stage than in Fig. 18.3 to show the fate of the ventral mesogastrium

from its ventral border (future lesser curvature) to the developing diaphragm and anterior abdominal wall (Figs 18.2 and 18.3). The liver develops in intimate proximity to this mesogastrium. After the formation of the liver, the peritoneum of the ventral mesogastrium passes from the stomach to the liver, covers the greater part of the liver, and is then reflected from the liver to the diaphragm and anterior abdominal wall (Fig. 18.4). The part of the

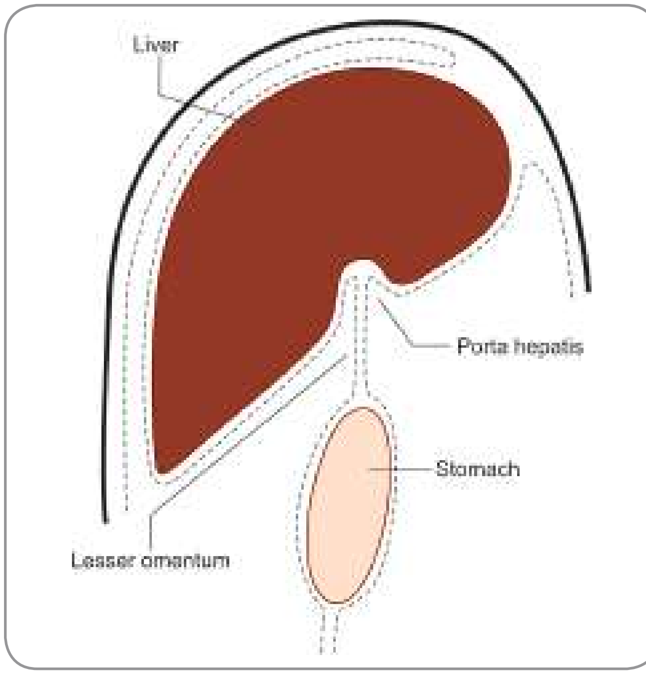


Fig. 18.5: Schematic parasagittal section through the liver to show its basic peritoneal relations

ventral mesogastrium between the stomach and the liver becomes the lesser omentum. The lesser omentum gains attachment (partly) to an area on the visceral surface of the liver called the porta hepatis (Fig. 18.5). Here, the two layers of peritoneum forming it separate to cover the greater part of the liver surface. The peritoneum from the surface of the liver is reflected on to the diaphragm (and the anterior abdominal wall).

Development

The liver develops from an endodermal bud (hepatic bud/diverticulum), that arises from the ventral aspect of the gut (at the junction of the foregut and midgut and in relation to the septum transversum). The endodermal bud divides into a larger cranial part called ***pars hepatica*** and a smaller caudal part called ***pars cystica***. The pars hepatica divides into the right and left parts, each of which forms the corresponding lobe of the liver. The endodermal cells of the hepatic bud give rise to parenchyma of the liver and the intrahepatic biliary ducts. The mesoderm of septum transversum forms the capsule and the fibrous tissue of the liver.

SURFACES AND RELATIONS

The liver has basically two surfaces (Fig. 18.6). Superiorly, it has a convex ***diaphragmatic surface***, and inferiorly it has an inferior or ***visceral surface***. The diaphragmatic surface is extensive. Part of it faces forwards, part of it upwards, and part of it backwards. These parts are sometimes referred to as anterior, superior and posterior surfaces but there are no distinctive features which demarcate them from one

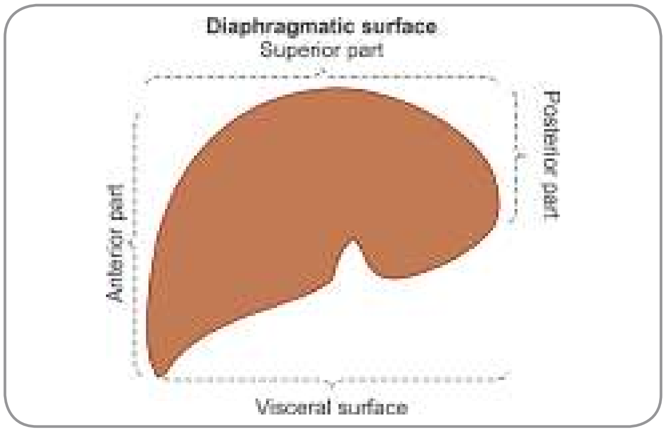


Fig. 18.6: Schematic sagittal section through the liver to show its surfaces

another. The diaphragmatic and visceral surfaces meet in front at a sharp ***inferior border***. Posteriorly, the junction of the two surfaces is rounded and not sharply defined.

Diaphragmatic Surface

The liver is shown as seen from the front in Figure 18.7 and as seen from above in Figure 18.8. In both these figures, we see the anterior and superior parts of the diaphragmatic surface. The anterior part of the diaphragmatic surface is covered by peritoneum except along a line near the median plane. Along this line, the peritoneum is reflected off from the liver to the diaphragm, and to the upper part of the anterior abdominal wall as the ***falciform ligament***. The line of attachment of the falciform ligament has traditionally been used to divide the liver into a larger right lobe and a much smaller left lobe. However, most authorities agree that the division of the liver into right and left lobes should be based on the areas drained by the right

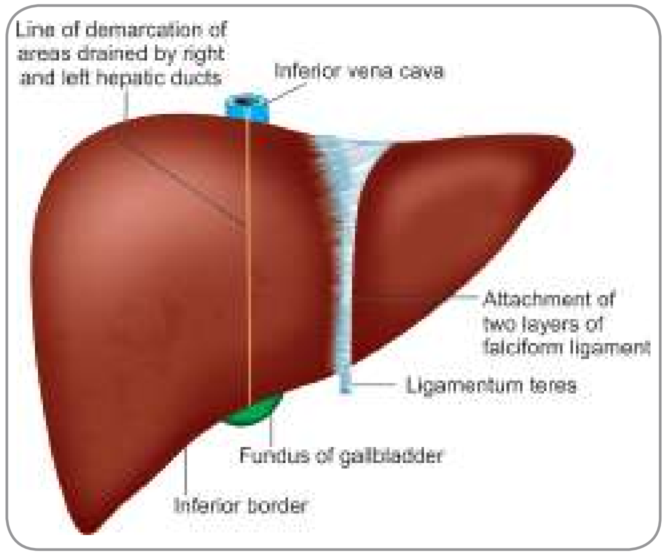


Fig. 18.7: Liver viewed from the front

and left hepatic ducts. This plane of division is shown in Figure 18.7 in yellow line. Apart from the falciform ligament, peritoneum from the superior part of the diaphragmatic surface is reflected on to the diaphragm in the form of ***left triangular ligament, superior layer of the coronary ligament and right triangular ligament*** (Figs 18.8 and 18.9). The posterior aspect of the liver is marked by a deep notch for the vertebral column (Fig. 18.8). To the right of this notch is a deep groove for the inferior vena cava.

The liver is shown as seen from behind in Figure 18.9. The upper part of this figure shows the posterior part (and adjoining superior part) of the diaphragmatic surface. The lower part of the figure shows the visceral surface (better seen in Figure 18.10). In Figure 18.9 identify some features already noticed in Figure 18.8. These are the attachments

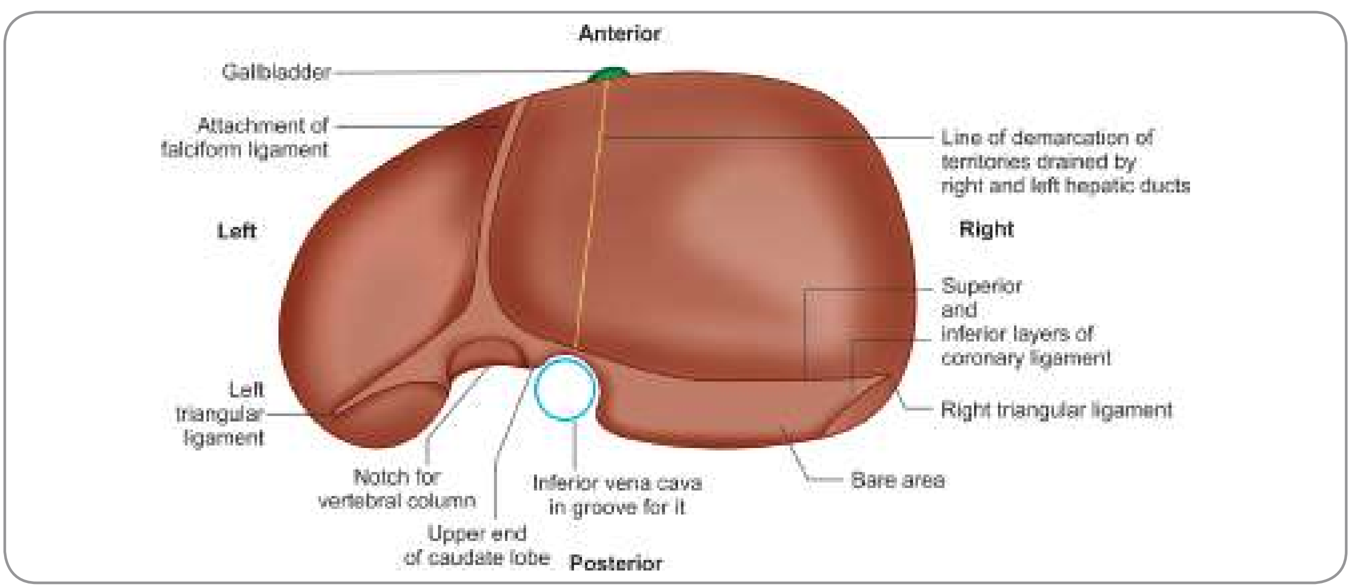


Fig. 18.8: Liver viewed from above

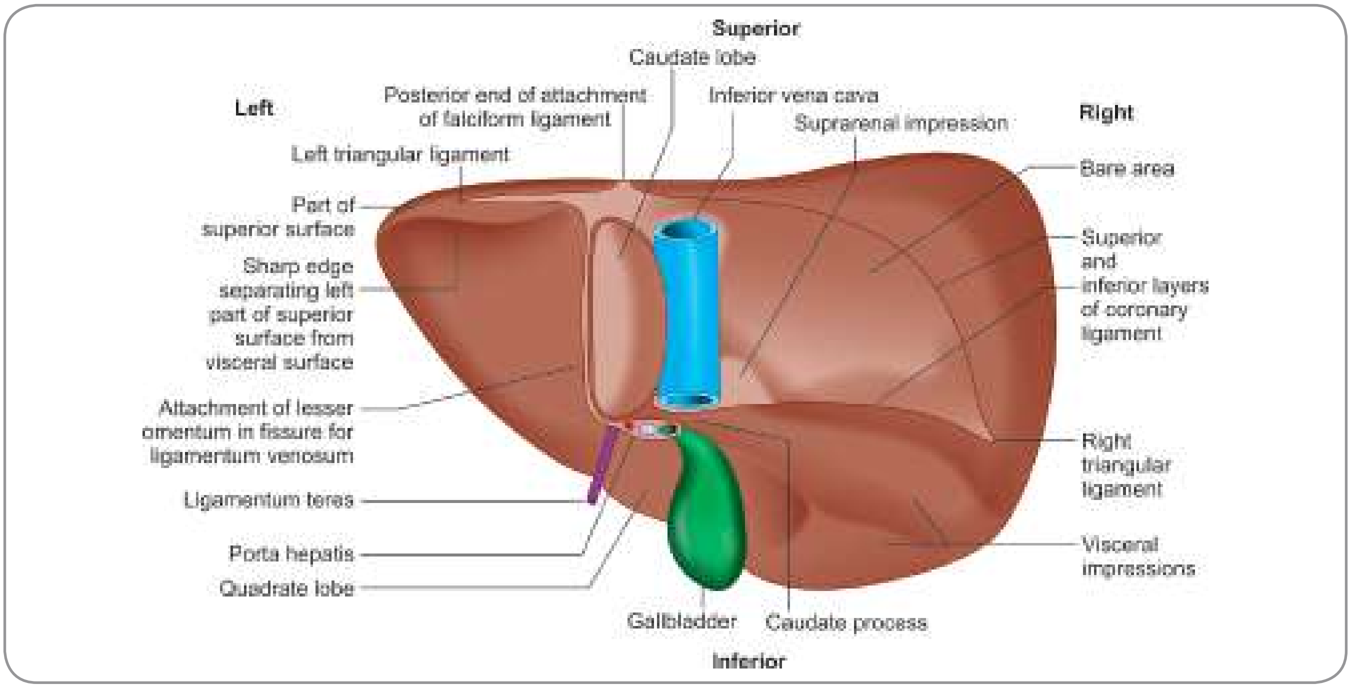


Fig. 18.9: Liver viewed from behind

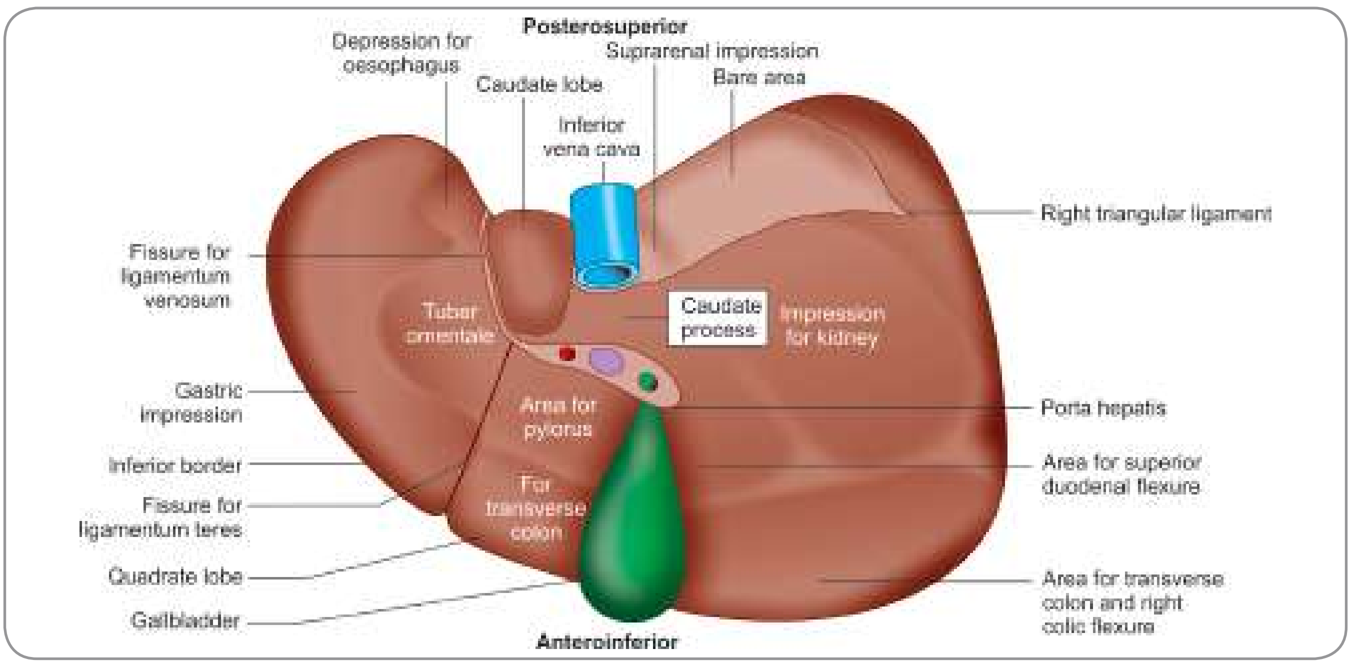


Fig. 18.10: Ventral surface of the liver seen from behind and below

of the left triangular ligament, the upper layer of the coronary ligament, the right triangular ligament, and the groove for the inferior vena cava. A considerable area on the posterior part of the diaphragmatic surface of the liver is not covered by peritoneum and is, therefore, called the ***bare area***. It includes the groove for the inferior vena cava and a large triangular area on the right of it. The triangle is bounded above by the attachment of the superior layer of the coronary ligament and below by the attachment of the inferior layer of the same ligament. These two layers meet towards the right side to form the right triangular ligament. To the left of the groove for the inferior vena cava there is a circumscribed part of the posterior surface that is called the ***caudate lobe***. The caudate lobe is bounded on its left side by a deep groove called the ***fissure for ligamentum venosum***. Inferiorly, the caudate lobe is separated from the visceral surface by the ***porta hepatis*** (which is in the form of a transverse groove; Latin.portere=to carry). The porta hepatis is the 'hilum' of the liver. The hepatic artery and portal vein enter the liver here, while the right and left hepatic ducts leave it.

The porta hepatis and the fissure for the ligamentum venosum give attachment to the two layers of the lesser omentum. The attachment is L-shaped when seen from behind, and in the form of an inverted 'L' when visualised from the front. The structures entering or leaving the liver at the porta hepatis (portal vein, hepatic artery, bile duct) are enclosed between the two layers of peritoneum forming the lesser omentum. The two layers become continuous with each other at the right end of the porta hepatis. This represents the upper end of the right free margin of the lesser omentum. A narrow strip of liver tissue intervenes between the posterior aspect of the porta hepatis and the groove for the inferior vena cava. This strip projects downwards and is called the ***caudate process*** (Latin. cauda=tail, caudate=tail like). It connects the caudate lobe (on the left) to the visceral surface of the right lobe (on the right). The caudate process forms the upper boundary of the aditus to the lesser sac (Fig. 18.10). At the junction of lower end and left margin there is a small projection called the ***papillary process***.

Visceral Surface

The most conspicuous feature on the visceral surface of the liver is the gallbladder. It lies in a depression on the liver surface called the ***fossa for gallbladder***. This fossa is not usually exposed to view as the gallbladder is fixed to the liver by peritoneum as shown in Figure 18.11. Starting near the right end of the porta hepatis the gallbladder runs downwards and forwards across the visceral surface of the liver. Another conspicuous feature seen on the visceral surface is the ***fissure for ligamentum teres***. This fissure runs from the left end of the porta hepatis to the inferior margin of the liver. It lodges the ligamentum teres. The part of the visceral surface between the fissure for ligamentum teres and the fossa for the gallbladder is called the ***quadrate lobe*** (because of its quadrangular shape). It is bounded posteriorly and above by the porta hepatis, and anteriorly and below by the inferior margin of the liver. In relation to the diaphragmatic surface, it has been mentioned that the attachment of the falciform ligament is used to divide the liver into right and left lobes. On the visceral surface, the line of division runs along the fissure for ligamentum venosum and the fissure for ligamentum teres. However, in terms of the territory of drainage of the right and left hepatic ducts the caudate and quadrate lobes are to be regarded as parts of the 'left' lobe.

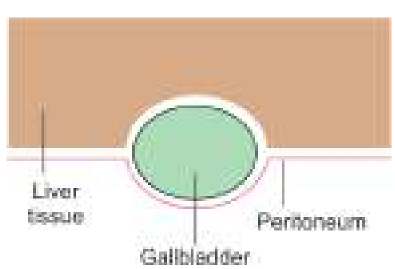


Fig. 18.11: Section through the fossa for gallbladder

The visceral surface of the liver comes into contact with several other viscera (Figs 18.9 and 18.10). A strip along the inferior margin comes in contact with the transverse colon (colic area). It includes the lower (anterior) part of the quadrate lobe, lower part of the gallbladder and lower part of the area to the right of the gallbladder. The right end of this strip comes in contact with the right colic flexure. The oesophagus comes in contact with a depression to the left of the upper end of the fissure for ligamentum venosum (oesophageal area). The depression is located on the posterosuperior margin of the visceral surface. The part of the visceral surface to the left of the fissures for ligamentum venosum and ligamentum teres comes in contact with the stomach and with the lesser omentum (gastric and omental areas). The area for the stomach is in the form of a shallow depression called the ***gastric impression***. The area in contact with the lesser omentum is raised. The elevation is called the ***tuber omentale.*** The pylorus comes in contact with the posterosuperior part of the quadrate lobe (pyloric area). The first part of the duodenum crosses the upper part of the gallbladder, while the superior duodenal flexure comes into contact with an area immediately to the right of the upper part of the gallbladder (duodenal areas). To the right of the area for the superior duodenal flexure, and above the area for the transverse colon, the visceral surface bears a large impression for the right kidney (renal impression). The liver comes in contact with the right suprarenal gland above and medial to the impression for the kidney (suprarenal area). The suprarenal produces a depression on the bare area immediately to the right of the lower part of the inferior vena cava.

LOBES AND SEGMENTS OF LIVER

Gross Anatomical Lobes

The liver has been traditionally divided into right and left lobes using certain surface features. On the anterior and superior parts of the diaphragmatic surface, the line of demarcation is the attachment of the falciform ligament. On the posterior part of the diaphragmatic surface, the line of demarcation is the fissure for ligamentum venosum. On the visceral surface, the demarcation is by the fissure for ligamentum teres. According to this plan of division, the caudate and quadrate lobes form part of the right lobe.

Sometimes a tongue-like projection from the inferior border is seen and is called Riedel's lobe (named after the 19th century German surgeon Bernhard MCL Riedel).

Functional Anatomical Lobes

The liver is drained by two ***hepatic ducts***, right and left which join to form the ***common hepatic duct***. It is rational to regard the territory drained by the right hepatic duct as the true or functional right lobe and that drained by the left hepatic duct as the true or functional left lobe. The line of demarcation between the two territories runs (posteriorly) along the groove for inferior vena cava and (inferiorly) roughly along the fossa for gallbladder. On the anterosuperior part of the diaphragmatic surface, demarcation is not marked by any surface feature. It can be represented roughly by a line joining the fundus of the gallbladder and the upper end of the inferior vena cava (yellow lines in Figs 18.7 and 18.8). The caudate and quadrate lobes lie in the territory drained by the left hepatic duct.

Hepatic Segments

Each lobe, thus defined is divisible into a number of segments based on the branching pattern of the hepatic ducts and vessels within the liver. A simplified scheme of these segments are shown in Figure 18.12.

The 'left' lobe is divided into medial and lateral parts. The lateral part corresponds to the traditional left lobe. The medial part lies to the right of the attachment of the falciform ligament. On the visceral surface, it corresponds to the quadrate lobe and the caudate lobe. The medial and lateral parts of the left lobe are each divided into superior and inferior segments. The caudate lobe is described as an independent segment (because it is supplied by both right and left branches of hepatic artery and portal vein and drained by both right and left hepatic ducts).

The 'right' lobe is divided into the anterior and posterior parts each of which is subdivided into the superior and inferior segments. There are thus a total of nine segments. It is important to remember, however, that there are no surface features to outline the segments, and that there is considerable individual variation in the size and relationship of individual segments to the surface of the liver. The subdivision is, therefore, not very useful to a surgeon wanting to remove a part of the liver.

PERITONEAL FOLDS OF LIVER

Lesser Omentum

Other names: Omentum minus, gastrohepatic omentum, omentulum.

The lesser omentum (Latin.oment=covering of intestines) consists of two layers of peritoneum which are continuous with the peritoneum lining the anterior and posterior surfaces of the stomach (Fig. 18.13). It is attached by its lower edge to the lesser curvature of the stomach and to the proximal portion of the first part of the duodenum. Its upper edge has a reversed 'L' shaped attachment to the liver. This attachment is to the fissure for the ligamentum venosum and to the lips of the porta hepatis (Fig. 18.10). Extending between the duodenum and the right extremity of the porta hepatis, the lesser omentum has a free edge (called the right free margin) formed by the continuity of the anterior and posterior layers. The structures which lie between the two layers of the omentum near its free edge are—the

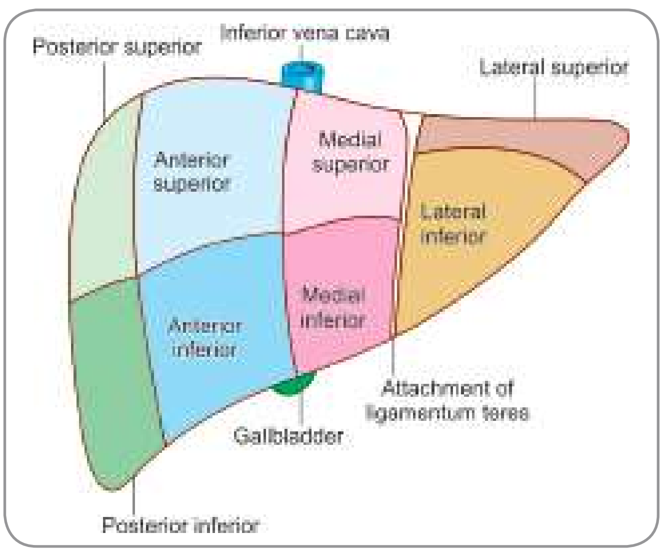


Fig. 18.12: Scheme to show the segments of liver

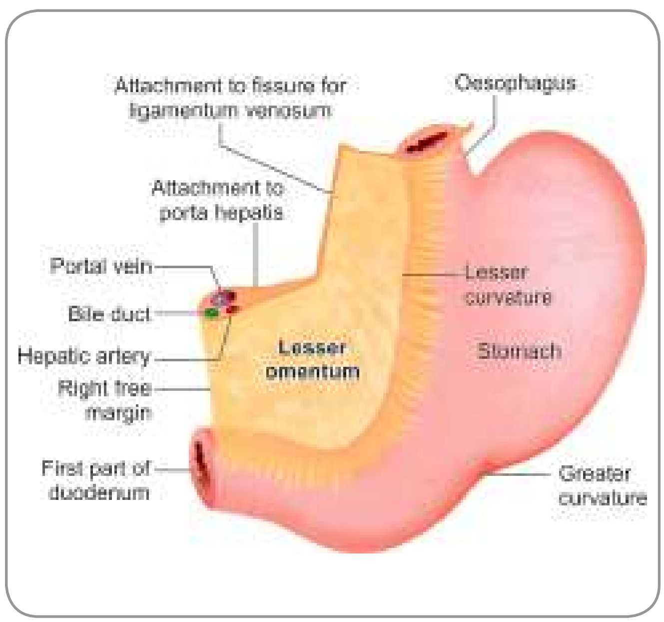


Fig. 18.13: Scheme to show the arrangement of the lesser omentum

portal vein, the bile duct and the hepatic artery. Along the lesser curvature of the stomach, the right and left gastric arteries and corresponding veins lie within the omentum. Some lymph nodes are also present. The lesser omentum forms part of the anterior wall of the lesser sac. The right free margin of the omentum forms the anterior boundary of the aditus to the lesser sac. The anterior layer of peritoneum forming the omentum can be traced down to the front of the pylorus and the commencement of the duodenum.

Relationship of Peritoneum to the Caudate Lobe

The caudate lobe is bounded on the left side by the fissure for ligamentum venosum. The lesser omentum is attached to this fissure (18.10). The lesser omentum extends to the bottom of the fissure where its layers are reflected on to the walls of the fissure. At the right margin of the posterior surface of the caudate lobe (i.e., near the inferior vena cava) the peritoneum is reflected from the caudate lobe to the diaphragm. In this way, a narrow recess of the cavity of the lesser sac comes to lie behind the caudate lobe. This is called the ***superior recess of the lesser sac***. The peritoneum lining the posterior surface of the caudate lobe is reflected on to the diaphragm along the upper border of the lobe thus forming the upper limit of the superior recess of the lesser sac.

Falciform Ligament

Other names: Falcular ligament, ligamentum falciforme hepatis.

The falciform ligament (Latin.falx=sickle) is attached on the anterior and superior parts of the diaphragmatic surface of the liver. The ligament is shaped like a sickle or is crescentic shaped. Its lower part is attached anteriorly to the anterior abdominal wall, the attachment extending up to the level of the umbilicus; posteriorly, it has a free edge formed by the continuity of the two layers of peritoneum (right and left) which form the ligament. The upper part of the ligament is a short fold passing from the diaphragm to the liver. The ligamentum teres is enclosed within the falciform ligament (near its free edge). It passes from the umbilicus to the inferior border of the liver within the ligament.

The right layer of the falciform ligament is continuous with the superior layer of coronary ligament on the right lobe and the left layer is continuous with the anterior layer of the left triangular ligament on the left lobe.

Coronary Ligament

The coronary ligament is made up of two layers (superior and inferior) of peritoneum which pass from the diaphragm to the posterior part of the diaphragmatic surface of the liver (Figs 18.8 and 18.9). The superior and inferior layers form the upper and lower boundaries (respectively) of the bare area of the liver. Towards the right side, the superior and inferior layers meet at an acute angle to form the right triangular ligament. When traced to the left side, the superior layer of the coronary ligament becomes continuous with the right layer of the falciform ligament. The inferior layer passes in front of the groove for the inferior vena cava, along the posterior edge of the caudate process and becomes continuous with the line of reflection of peritoneum along the right margin of the caudate lobe (Fig. 18.9). The inferior layer is actually reflected from the liver to the right kidney and hence, is called the hepatorenal ligament.

Left Triangular Ligament

The left triangular ligament connects the upper surface of the left lobe of liver to the diaphragm. It consists of two layers—anterior and posterior. The anterior layer becomes continuous with the left layer of falciform ligament and the posterior layer becomes continuous with the anterior layer of lesser omentum at the upper end of the fissure for ligamentum venosum.

Right Triangular Ligament

The right triangular ligament connects the posterior surface of the right lobe of liver to the diaphragm. It forms the apex of the bare area of the liver and also forms the right limit of the superior and inferior layers of the coronary ligament.

Added Information

Peritoneal Spaces around the Liver

Surrounding the liver are a number of regions where the peritoneum covering the surface of the liver is separated from the peritoneum lining the diaphragm, or the peritoneum covering the adjoining viscera, only by a potential space. The spaces lying between the diaphragm and the liver are referred to as ***subphrenic spaces***. Spaces inferior to the liver are called ***subhepatic spaces.*** The importance of the subphrenic and subhepatic spaces is that they are sites where abnormal fluids (like pus) can collect. Normally, all parts of the peritoneal cavity are in communication with each other, but in the presence of infection abnormal adhesions may form and pockets may become isolated. From this point of view, it is of importance to define the regions where such collections and adhesions may happen.

The ***right subphrenic space*** is bounded, on the left side by the falciform ligament, and behind by the superior layer of the coronary ligament. Anteriorly and to the right, it becomes continuous with the rest of the peritoneal cavity at the lower border of the liver. The ***left subphrenic space*** is bound on the right side by the falciform ligament, and behind by the left triangular ligament. Anteriorly and to the left, it is in communication with the part of the peritoneal cavity intervening between the stomach and spleen (below) and the diaphragm (above).

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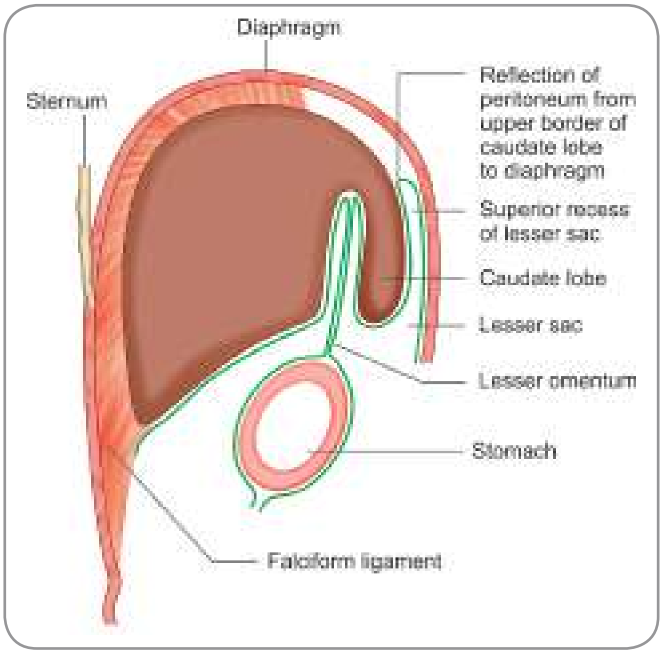


Fig. 18.14: Sagittal section through the caudate lobe of the liver showing its peritoneal relations

Added Information

The ***right subhepatic space*** is also called the ***hepatorenal*** or ***Morison's pouch*** (named after the 18th-19th century British surgeon James Rutherford Morison). It lies below the right half of the visceral surface of the liver. The gallbladder lies anterior to this pouch. Posteriorly (and below), the pouch is related to the right kidney, the transverse colon and the descending part of the duodenum. Inferiorly, the space is continuous with the rest of the peritoneal cavity. This space is a gravity-dependent part in supine position. It is one (upper) of the two most dependent parts of the peritoneal cavity. Fluid draining from the omental bursa collects in this space. The gallbladder and the duodenum may rupture into this pouch. Even fluid travelling from a ruptured appendix may track to this space. The ***left subhepatic space*** is merely another name for the lesser sac (omental bursa). The intimate relationship of the superior recess of this sac to the caudate lobe (Fig. 18.14).

BLOOD VESSELS

The liver receives oxygenated blood through the hepatic artery. This artery is a branch of the coeliac trunk. Entering the liver at the porta hepatis, it divides into two main branches which are distributed to the 'true' right and left lobes. The branching pattern of the artery corresponds to that of the hepatic ducts. Each hepatic segment (Fig. 18.12) receives one major branch. The terminal branches of the hepatic artery are functional end arteries, the anastomoses between them being insignificant. The liver receives blood from the gastrointestinal tract through the portal vein. At the porta hepatis, the portal vein divides into right and left branches which accompany the branches of the hepatic artery.

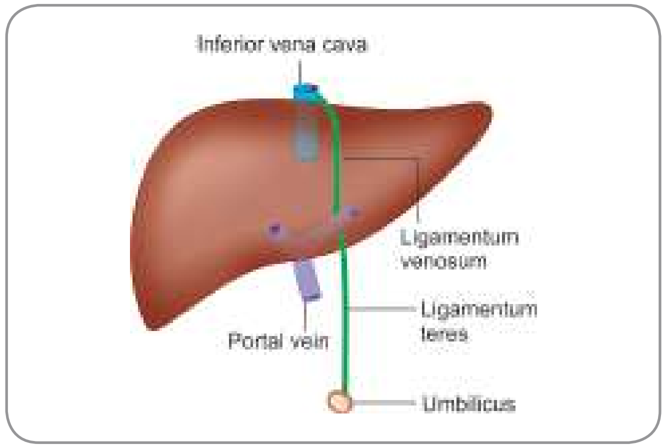


Fig. 18.15: Scheme to show the ligamentum teres and the ligamentum venosum

Blood from the liver is drained by a number of hepatic veins which open directly into the inferior vena cava. Though may, it has been customary to describe three major hepatic veins, right, middle and left hepatic veins.

Development

Developmental Significance of Ligamentum Teres and Ligamentum Venosum

In foetal life, oxygenation of blood takes places not in the lungs, but in the placenta. Blood from the placenta is brought to the foetus initially through right and left ***umbilical veins***. The right vein is transitory and soon disappears so that all blood now comes to the foetus through the left umbilical vein. The left umbilical vein ends initially in the left horn of the sinus venosus, but later in foetal life it ends by joining the left branch of the portal vein. For some time during foetal life, all blood coming from the placenta has to filter through the liver before reaching the heart. However, at a later stage, a new channel called the ***ductus venosus***, short circuits a large part of this blood to the inferior vena cava because there is no necessity to purify, in the liver, the already purified placental blood. The ductus venosus is connected at one end to the left branch of the portal vein, and at the other end to the inferior vena cava. After birth, the left umbilical vein and the ductus venosus are no longer functional. They retrogress into fibrous structures. The left umbilical vein becomes the ligamentum teres, and the ductus venosus becomes the ligamentum venosum (Fig. 18.15). The ligamentum teres, therefore, begins at the umbilicus and ends by joining the left branch of the portal vein, while the connections of the ligamentum venosum are those of the ductus venosus.

LYMPHATIC DRAINAGE

The lymphatic drainage of the liver is into the nodes around the upper end of inferior vena cava, nodes in the porta hepatis and the coeliac nodes.

The liver is drained by two sets of lymphatics—the superficial and the deep.

The ***superficial lymphatics*** form a network in the subperitoneal fibrous capsule of the liver called the Glisson's capsule. They drain into the pericaval nodes, hepatic nodes, coeliac nodes, paracardiac nodes and the phrenic nodes.

The ***deep lymphatics*** accompany the portal triads and the ramifications of the hepatic veins. They join to form the ascending and descending trunks. The ascending trunks accompany the hepatic veins and drain into the nodes around the inferior vena cava. The descending trunks emerge out of the porta hepatis and drain into the hepatic lymph nodes. The efferents from the hepatic nodes pass to the coeliac nodes which in turn drain into the cisterna chyli.

NERVE SUPPLY

The nerve supply to the liver is derived from the hepatic plexus that accompanies the branches of the hepatic artery and the portal vein. The plexus is derived from the coeliac plexus and contains both sympathetic and parasympathetic fibres. The sympathetic fibres are derived from the coeliac plexus and the parasympathetic fibres from the anterior and posterior vagi. Though the nerve fibres have been traced to the portal triads of the hepatic lobules, their function is unclear except that the sympathetic fibres have been found to produce vasoconstriction.

Histology

Liver is surrounded by a thin connective tissue capsule (called the ***Glisson's capsule***) from which numerous trabeculae or interlobular septa pass into the parenchyma. Branches of the hepatic artery and portal vein together with bile ductules run in these connective tissue septa which are also called ***portal canals***. ***Space of Mall*** is the space surrounding the blood vessels and bile ductules within the portal canals.

Liver parenchyma is mainly made up of hepatocytes supported by connective tissue. The ***structural unit*** of the liver is the classic ***hepatic lobule***. The lobule comprises plates of hepatocytes arranged hexagonally and separated by intervening sinusoids. The sinusoids radiate from a central vein at the centre of the hepatic lobule to the portal triads which occupy the corners of the hexagon. Each portal triad contains a portal venule, a hepatic arteriole and a bile ductule.

Apart from the hepatic lobule which is the structural unit, one other lobule is present in the liver; it is called the ***portal lobule***. The portal lobule is a triangular area that includes parts of three classic hepatic lobules; the portal triad occupies the central position of this lobule and the central veins occupy the corners. The portal lobule is considered the ***functional unit*** of liver.

Hepatic acinus is yet another entity that should be understood. It is elliptical in shape and includes parts of two classic hepatic lobules with the central veins at the corners and branches of hepatic arteriole and portal venule at the centre.

contd...

Histology *contd...*

Sinusoidal capillaries are present between the plates of hepatocytes. ***Perisinusoidal space (called the Space of Disse)*** is the space between the basal surfaces of sinusoidal endothelium and the hepatocytes. Exchange of material between blood and hepatocytes takes place in the space of Disse. The sinusoids receive an admixture of blood from the hepatic arterioles and the portal venules. Blood flows ***centripetally*** towards the central vein. The central veins from adjacent hepatic lobules converge to form sublobular veins which then drain into hepatic veins. The hepatic veins emerge from the liver substance to drain into the inferior vena cava.

Hepatic sinusoids are lined by discontinuous ***sinusoidal endothelial cells*** and ***Kupffer cells*** (which are the hepatic macrophages). Hepatic ***stellate cells (called the Ito cells)*** are found in the perisinusoidal spaces. They are involved in storage of vitamin A. ***Bile canaliculi*** are small channels formed by plasma membranes of opposing hepatocytes into which the hepatocytes secrete bile. Bile flow is centrifugal from the central vein towards portal canal. Bile canaliculi carry bile to the bile ductule in the portal triad through ***canals of Herring***.

Added Information

- ***H-fissure on the visceral surface of liver:*** Two sagittal fissures are interconnected by a transverse fissure to form a H on the visceral surface of the liver. The transverse fissure is the porta hepatis. The right sagittal fissure is formed by the fossa for gallbladder anteroinferiorly and the groove for inferior vena cava posterosuperiorly. The left sagittal fissure is formed by the fissure for ligamentum teres anteroinferiorly and the fissure for ligamentum venosum posterosuperiorly.
- ***Intrahepatic biliary passages:*** Bile is formed by the hepatocytes. This bile flows into the biliary canaliculi which are merely clefts between the hepatocytes. The biliary canaliculi are also called the intralobular bile ductules. These ductules flow into the interlobular biliary ducts (small ducts which form part of the interlobular portal triad and are lined with cubical cells). The interlobular ducts join to form larger collecting ducts. The collecting ducts join to form the right and left hepatic ducts. The right and left hepatic ducts emerge out of the liver at the porta hepatis. The intralobular bile ductules, interlobular bile ductules and collecting ducts collectively form the intrahepatic biliary system.
- ***Concept of hepatic lobule:*** The microstructure of liver is customarily described on the basis of the hepatic lobule. Each lobule has a central vein. Radiating from the centre to the perimeter of the lobule are the hepatic sinusoids and the hepatocytes. At the perimeter (at six angles due to the hexagonal shape of the hepatic lobule), the portal triads are found. However, research has shown that this hepatic lobule is not a structural or an anatomical entity. The hexagonal pattern is consequential to physiological pressure levels and is altered in disease conditions. The hepatic lobule is also not a functional unit of the glandular part of the liver since the bile duct is not a central structure of the lobule (in an acinus, the duct is the central structure).

contd...

Added Information *contd...*

- The ligamentum teres (also called the round ligament of the liver or the ligamentum teres hepatis) is the fibrous remnant of the left umbilical vein that carries, during foetal life, oxygenated blood from the placenta to the foetal body. From the umbilicus to the inferior margin of the liver, it occupies the free margin of the falciform ligament. On the visceral surface of the liver, it occupies the fissure for ligamentum venosum.
- The ligamentum venosum is the fibrous remnant of the foetal ductus venosus. The ductus venosus connected the umbilical vein and the inferior vena cava in the foetus, thus shunting blood from the umbilical vein to the IVC circumventing the liver.
- The falciform ligament, is developmentally the mesentery of the umbilical vein.
- The liver is a major lymph producing organ. Atleast 40% of the lymph entering the thoracic duct comes from the liver. Most of the lymph is formed in the perisinusoidal spaces of Disse.
- In addition to the regularly described 'bare area' between the coronary ligaments, the fossa for gallbladder and the small space between the diverging layers of the falciform ligament on the superior aspect of the liver are also described as two other bare areas of the liver.
- The caudate lobe of the liver has been so named because it is connected to the rest of the organ by the caudate process.

Clinical Correlation

Palpation of the liver

The surface projection of the liver is shown in Figure 18.1. Note that part of the anterior surface of the liver comes into contact with the anterior abdominal wall in the epigastrium. However, the liver cannot be palpated here because it is covered by the rectus abdominis muscles. Dullness in the area can, however, be elicited on percussion. The lower border of an enlarged liver extends beyond the right costal margin and can be palpated, especially after a deep breath.

Congenital Anomalies

These are rare and mostly involve abnormalities in formation of fissures and lobes. Part of the liver may be missing. Ectopic liver tissue may be present in the falciform ligament.

Injury

Injury to the liver can occur by fracture of the lower ribs. Injury to the organ is common in automobile accidents. Laceration of the liver leads to considerable haemorrhage.

Liver Infections and Damage

Liver tissue can be damaged by infections and by toxic substances reaching it through the bloodstream. Inflammation of the liver is called ***hepatitis*** (hepar = liver). Hepatitis is often viral. The infection can reach the liver through contaminated drinking water. Hepatitis can also be spread through needles used for injection. Severe viral infections can lead to serious liver damage. They can also predispose to cancer. Infection with *Entamoeba histolytica* leads to ***amoebic hepatitis***. This is usually secondary to intestinal infection. Amoebic hepatitis can lead to the formation of an ***amoebic abscess***. Various other infections may occur.

contd...

Clinical Correlation *contd...*

All substances absorbed into the bloodstream from the gut pass, through the portal vein, into the liver. Apart from nutrients these include alcohol and drugs. The liver tries to detoxify harmful substances before they are passed into the systemic circulation, but in the process, the liver tissue can itself undergo damage. In persons who consume excessive amounts of alcohol over long periods of time, the liver tissue undergoes fibrosis (***cirrhosis of liver***). The liver tissue has considerable reserve and continues to carry out its normal functions even after large amounts of it are damaged. However, as damage progresses, liver failure can set in. Coma occurring as a result of liver failure is called ***hepatic coma***.

Tumours of the Liver

Tumours of the liver may arise either from liver cells or from cells lining bile capillaries. They may be benign (hepatoadenoma, cholangioadenoma) or malignant (hepatocarcinoma, cholangiocarcinoma). The liver is also a common site for secondary growths (metastases) caused by malignancy elsewhere in the body.

Liver Biopsy

A small piece of liver tissue can be obtained for examination by introducing a needle into the organ. The needle is usually introduced through the right 8th or 9th intercostal space and is passed through the diaphragm. Biopsy material can also be obtained through the epigastrium.

Surgery on the Liver

In cases of injury, the main aim of surgery is to control bleeding. For excision of tumours, parts of the liver may require surgical removal. The surgeon tries to remove as little liver tissue as possible. For this purpose, knowledge of the segments of the liver is essential. Sometimes, entire lobes may have to be removed (examples ***right hemihepatectomy*** or ***left hemihepatectomy***).

Dissection

Before trying a dissection scheme, study the liver, gallbladder and pancreas in prosected specimens. Observe the peritoneal relations of these organs. After this initial study, turn your attention to specimens with the organs *in situ*. Look out for the falciform ligament and its attachments. Try to mobilise the liver to a ***small extent*** and study its visceral aspect. Try to see the adjacent structures in position and observe the relationship that the liver has to these structures. Study the pancreas in a specimen that has an intact posterior abdominal wall. Observe the C loop of duodenum and try to trace the pancreaticoduodenal arterial arcades. Return to a specimen that has the loops of intestine and transverse colon in position. Lift the transverse colon to note its relation to the pancreas; observe the attachments of the transverse mesocolon.

EXTRAHEPATIC BILIARY APPARATUS

The passages through which bile, produced in the liver, passes before entering the duodenum are seen in Figure 18.16. The ***right*** and ***left, hepatic ducts*** emerge at the porta hepatis and join to form the ***common hepatic duct***.

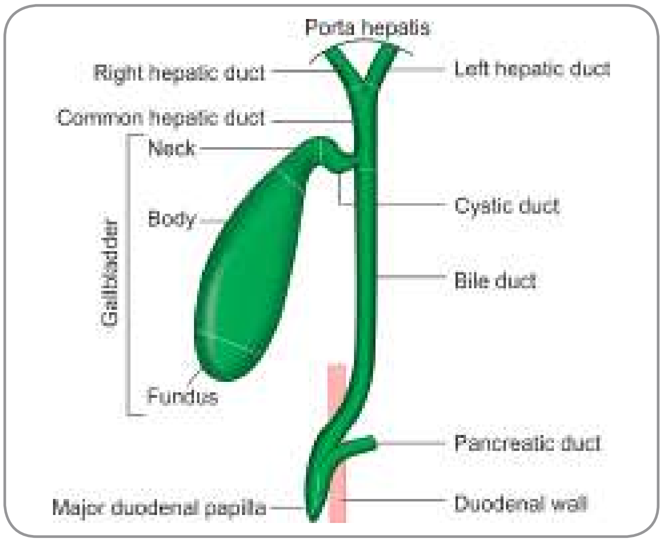


Fig. 18.16: Scheme to show the parts of the extrahepatic biliary apparatus

At its lower end, the common hepatic duct is joined by the ***cystic duct*** from the ***gallbladder*** to form the ***bile duct***. The bile duct opens into the duodenum.

The biliary passages which transmit bile from the liver to the duodenum and are found outside the liver are collectively indicated by the term 'extrahepatic biliary apparatus'. It consists of:

- Common hepatic duct
- Gallbladder
- Cystic duct and
- Bile duct

The commencement of the extrahepatic biliary apparatus is at the formation of common hepatic duct by the union of right and left hepatic ducts and termination is at the point where the bile duct unites with the pancreatic duct to form an ampulla, which opens on the major duodenal papilla.

Development

The pars cystica of the endodermal bud gives rise to the gallbladder and cystic duct. The two branches of the hepatic bud form the right and left hepatic ducts, which join to form the common bile duct. The part of the hepatic diverticulum caudal to the cystic bud forms the bile duct. The bile duct first opens into the ventral aspect of the duodenal loop; after differential growth of the duodenal wall and rotation of gut, it comes to open on the dorsomedial aspect of duodenum along with the ventral pancreatic bud.

Common Hepatic Duct

Other names: Hepatocystic duct, hepaticus communis.

The right and the left hepatic ducts drain the right and left parts of the liver. They emerge out of the porta hepatis and almost immediately join to form the common hepatic duct. They are usually very short and lie almost within the porta hepatis in that they do not appear to be 'extrahepatic' but appear to lie within the liver itself. The common hepatic duct is usually 1 or 2 cm long but may be longer depending on where the cystic duct joins it (being very short if the cystic duct joins it immediately outside the porta hepatis).

Gallbladder

Other names: Cholecyst, cholecystis, vesica fellea, cystis fellea.

The gallbladder is a small sac attached to the visceral surface of the liver (Fig. 18.10). It is held in place by peritoneum that covers its inferior (or posterior) surface (Fig. 18.11). Its superior (or anterior) aspect is in direct contact with the liver tissue. The lowest part of the gallbladder, which is called the ***fundus***, projects beyond the inferior border of the liver (Fig. 18.7) and is surrounded all around by peritoneum. The central part of the gallbladder is called the ***body***. The narrow part succeeding the body is called the ***neck***. The neck is connected to the ***cystic duct*** through which the gallbladder drains into the bile duct.

Histology

The gallbladder is made of three layers. From inside outwards, they are the mucous membrane, fibromuscular coat and a serous layer.

- ***Mucosa*** is thrown in to many ***folds*** giving a honeycomb appearance. The mucosal folds may appear like villi but can be differentiated by the absence of goblet cells. It is lined with simple columnar epithelium with microvilli on the surface (which helps in absorption of water from stored bile). It has an underlying lamina propria but muscularis mucosae and submucosa are absent.
- ***Fibromuscular*** layer is composed of fibrous tissue mixed with smooth muscle cells.
- ***Serous*** layer covers the gallbladder over the inferior surface only; the rest of the gallbladder is covered by adventitia.

Contraction of gallbladder is stimulated by cholecystokinin, a hormone produced by enteroendocrine cells in the duodenal mucosa.

Biliary ducts: Various names have been used to indicate different parts of the biliary duct system.

- The ducts which transmit bile from the liver are the right and left hepatic ducts.
- The confluence of the right and left hepatic ducts gives rise to the common hepatic duct or the hepatocystic duct.
- The cystic duct or the cystic gall duct is the duct that leads from the gallbladder to join the common hepatic duct.
- The bile duct or the common bile duct is the duct formed by the union of the common hepatic duct with the cystic duct.

Relations of the Gallbladder

Anteriorly, the body and neck of the gallbladder are in contact with the liver. The fundus comes in contact with the anterior abdominal wall just below the ninth costal cartilage. The area of contact corresponds to the point where the lateral margin of the right rectus abdominis muscle crosses the costal margin. The posterior (or inferior) relations of the gallbladder are—the transverse colon (near its right end) and the duodenum (the first part and beginning of the second part). The mucous membrane lining the neck of the gallbladder is folded in a spiral manner forming the so-called ***spiral valve***. This 'valve' extends into the cystic duct also. The gallbladder has a capacity of about 40 ml.

The gallbladder is supplied by the cystic artery (branch of the hepatic artery). It is drained by the cystic veins. Some of these veins enter the liver tissue directly, while the others join the veins draining the bile duct and ultimately drain into the portal vein. The lymphatic drainage is to the hepatic and cystic lymph nodes which in turn drain into the coeliac nodes. The nerve supply is by a plexus around the cystic artery and consists of sympathetic (fibres from the coeliac plexus), parasympathetic (fibres from the vagi) and somatic afferent (fibres from the right phrenic nerve) components. Parasympathetic stimulation causes contraction of the gallbladder and relaxation of the hepatopancreatic sphincters.

Cystic Duct

Other name: Cystic gall duct.

The cystic duct is about 3 to 4 cm long and runs from the neck of the gallbladder to the common hepatic duct. It usually joins the latter just inferior to the porta hepatis. If the cystic duct is longer, it runs in the free margin of the lesser omentum along with the common hepatic duct and joins the latter in the proximal part of the omentum. It contains the spiral valve formed by the mucosa.

Bile Duct

Former name: Common bile duct; ***other names:*** gall duct, choledochus, choledoch duct.

The bile duct extends from just below the porta hepatis to the middle of the descending part of the duodenum. It is about 7 cm long.

From above downwards it lies in the right free margin of the lesser omentum (Fig. 18.13), behind the first part of the duodenum and behind the head of the pancreas. Within the lesser omentum, the duct lies to the right of the hepatic artery and in front of the portal vein (Fig. 18.13). All the three structures lie anterior to the aditus to the lesser sac by which they are separated from the inferior vena cava. Behind the duodenum, the gastroduodenal artery lies to the left of the bile duct. Behind the pancreas, the duct

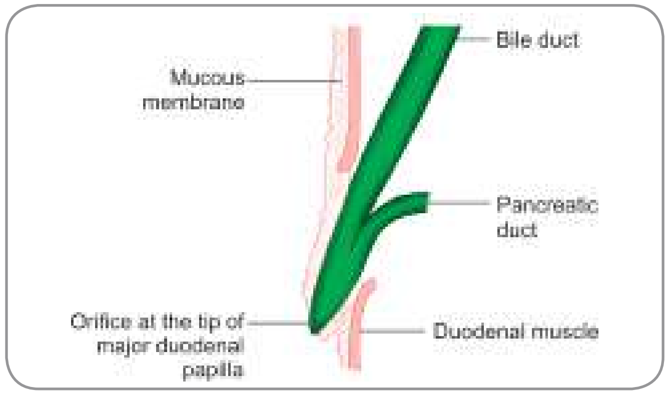


Fig. 18.17: Terminal parts of the bile and pancreatic ducts

lies in front of the inferior vena cava. This part of the duct may be embedded in pancreatic tissue. Just outside the duodenal wall the bile duct is joined by the pancreatic duct. The two ducts pierce the muscular wall of the duodenum obliquely (Fig. 18.17) and then descend in the submucosa. The bile and the pancreatic ducts may open separately on the major duodenal papilla, or may join (at a variable distance above the papilla) to form a common passage called the ***hepatopancreatic ampulla***.

The bile duct is supplied by branches from the cystic (supply for proximal part), right hepatic (supply for middle part) and superior pancreaticoduodenal (supply for distal part) arteries. The veins join those from the gallbladder and ultimately end in the portal vein. Veins from the upper part of the bile duct, hepatic duct, gallbladder and cystic duct enter the liver. Those veins from lower part enter the portal vein.

Lymphatics from the gallbladder and the bile duct drain into the hepatic nodes (including the cystic node) and the coeliac nodes.

Bile Duct and Pancreatic Duct

The bile duct descends posterior to the superior part of the duodenum. It then lies in a groove on the posterior surface of the pancreatic head. As this part of the bile duct lies to the left of the descending part of the duodenum, it comes in contact with the main pancreatic duct. Both the ducts run, for a short distance, obliquely through the wall of the duodenum. They then unite forming a dilatation called the hepatopancreatic ampulla (or the duodenal ampulla or the ampulla of Vater; named after the 17th century German anatomist Abraham Vater). The ampulla then opens into the duodenum through the major duodenal papilla.

Sphincters Related to the Bile Duct and Pancreatic Duct

The terminal part of the bile duct is surrounded (just above its junction with the pancreatic duct) by a ring of smooth muscle that forms the ***sphincter choledochus***

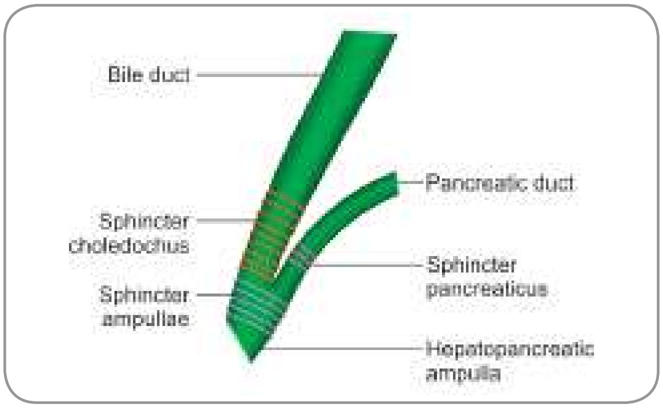


Fig. 18.18: Sphincters around the terminal parts of the bile and pancreatic ducts

(Fig. 18.18). This sphincter is always present. It normally keeps the lower end of the bile duct closed. As a result, bile formed in the liver keeps accumulating in the gallbladder (and also undergoes considerable concentration). When food enters the duodenum (especially a fatty meal) the sphincter opens and bile stored in the gallbladder is poured into the duodenum. The sphincter choledochus is, therefore, essential for filling of the gallbladder. Another less developed sphincter is usually (but not always) present around the terminal part of the pancreatic duct. This is the ***sphincter pancreaticus***. A third sphincter surrounds the hepatopancreatic ampulla and is called the ***sphincter ampullae***. The sphincter ampullae may extend upwards to enclose the lower parts of the bile and pancreatic ducts. The sphincters named above are often referred to collectively as the ***sphincter of Oddi*** (although this term strictly applies only to the sphincter ampullae; named after the 19th century Italian physician Ruggero Oddi).

Added Information

- The gallbladder is intimately related to the superior part of the duodenum. This is the reason that the superior part of the duodenum is usually found stained with bile in the cadaver. The body of the gallbladder lies anterior to the duodenum and the neck and the cystic duct lie superior.
- The neck of the gallbladder makes a typical S-bend before continuing into the cystic duct.
- The cystic duct is kept open by the spiral valve. This factor aids in the patency of the cystic duct so that bile can easily be diverted into the gallbladder if the hepatopancreatic sphincter is closed or can flow out during contraction of the gallbladder. The spiral valve also offers resistance to sudden dumping of bile during increase in intra-abdominal pressure.
- The cystohepatic triangle or the triangle of Calot is the anatomical indicator for the point of origin of the cystic artery. The triangle is formed by the common hepatic duct (medially), the cystic duct (laterally) and the visceral surface of liver (superiorly). The cystic artery arises from the right branch of the hepatic artery proper within the boundaries of this triangle.

contd…

Added Information *contd…*

- The veins of the fundus and body of the gallbladder usually enter into the visceral surface of the liver and drain into the hepatic sinusoids. This is drainage from one capillary bed (capillaries of gallbladder) to another capillary bed (hepatic sinusoids) and therefore, constitutes a portal system (cholecystohepatic portal system).
- The gallbladder is present in most vertebrates including fishes, dogs and cats, but is absent in horses, deer and pigeons.

Clinical Correlation

Congenital Malformations

The extrahepatic biliary system and its constituent parts may show several variations consequent to congenital malformations.

Gallbladder

The fundus of the gallbladder may be folded on itself to form a cap like structure called the ***phrygian cap***. The wall of the infundibulum may project downwards as a pouch (***Hartmann's pouch***) that may be adherent to the cystic duct or even to the bile duct. In the condition called ***floating gallbladder,*** the gallbladder is covered by peritoneum on all sides. Such a gallbladder can undergo torsion. Alternatively, the gallbladder may be embedded in liver substance. Instead of lying in its normal position, the gallbladder may lie transversely under the right lobe, or may lie under the left lobe of the liver. The gallbladder may open directly into the bile duct (***sessile bladder***), the cystic duct being absent. Agenesis, atresia or duplication may affect the gallbladder or one of the ducts.

Duct System

Any of the ducts may show abnormalities of length, atresia, or duplication. The cystic duct may have an abnormal termination. It may join the common hepatic duct on its left side (instead of the normal right side). It may end in the right hepatic duct. It may even open into the stomach. Sometimes, the cystic duct is very long and descends anterior to the duodenum before joining the common hepatic duct.

Inflammation and Stone Formation

Inflammation of the gallbladder is called ***cholecystitis***. Chronic cholecystitis is often associated with the formation of stones in the gallbladder (***cholelithiasis***). Surgical removal of the gallbladder is called ***cholecystectomy***. Pain arising in the gallbladder is felt over the right hypochondrium. The pain may radiate to the right scapula or right shoulder especially if the subdiaphragmatic parietal peritoneum is involved. To test for gallbladder inflammation, the physician places a finger over the site where the right costal margin meets the linea semilunaris (or at the tip of the 9th costal cartilage) and asks the patient to take a deep breath. The presence of sharp pain is referred to as ***Murphy's sign***. When a gall stone tries to pass through the bile duct it causes severe pain called ***biliary colic*** which is felt in the epigastrium.

contd…

Clinical Correlation *contd...*

Biliary Obstruction

Obstruction to the biliary duct system from any cause leads to the development of jaundice. Such obstruction is often associated with a tumour of the pancreas. In many cases, the bile and pancreatic ducts retain separate lumina right up to the tip of the major duodenal papilla. In some cases, they open into a common hepatopancreatic duct (or ampulla of Vater) that is highly variable in length. When this common duct is long, obstruction near the orifice (by a calculus or by spasm of muscle) can lead to regurgitation of bile into the pancreatic duct. This can lead to pancreatitis. The wall of the gallbladder may become adherent to that of the duodenum and erosion here may lead to the formation of a fistula between the two. Gall stones can thus pass into the duodenum. Following operations on the biliary tract, an ***external biliary fistula*** may form.

Radiological Techniques for Investigation of the Gallbladder

Oral Cholecystography

This is a method to visualise the gallbladder. A suitable radio-opaque dye is given by mouth. It is absorbed by the gut and reaches the liver through the portal circulation. It is then secreted into bile that is concentrated in the gallbladder making it visible in a skiagram.

Intravenous Cholangiography

A suitable radio-opaque dye is injected intravenously. It reaches the liver and is secreted into bile. It permits visualisation of the bile ducts.

PANCREAS

Other name: Sweet bread.

The pancreas is a large gland present in close relationship to the duodenum and stomach (Fig. 18.19). It lies obliquely on the posterior abdominal wall, partly to the right of the median plane and partly to the left. Its right end is enlarged and is called the ***head***. Next to the head is a short, somewhat constricted part called the ***neck***. The neck is continuous with the main part of the gland called the ***body***. The left extremity of the pancreas is thin and is called the ***tail.***

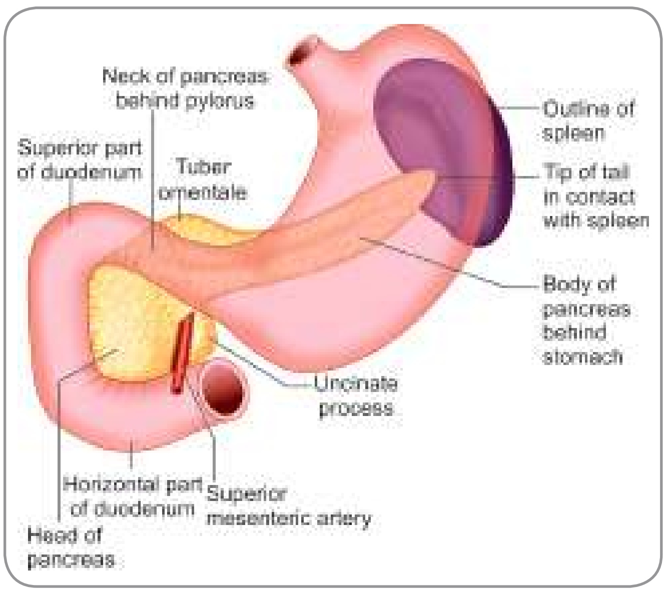


Fig. 18.19: Parts of the pancreas and their relationship to the stomach, the duodenum and the spleen

The head (caput) lies in the C-shaped space bounded by the duodenum. The neck is placed behind the pylorus and the body (corpus) of the pancreas lies behind the body of the stomach. The neck and body are separated from the stomach by the lesser sac. The tail (cauda) lies in the lienorenal ligament and its tip comes in contact with the spleen. A projection arising from the lower left part of the head is called the ***uncinate process*** of the pancreas (Fig. 18.19). The uncinate process has been variedly called the lesser pancreas, pancreaticus minor, small pancreas, Willis' pancreas and Winslow's pancreas.

Development

The pancreas develops from two pancreatic buds which arise from the junction of the foregut and midgut. The dorsal bud, first arises from the dorsal aspect of the gut tube. A little later, the ventral pancreatic bud arises below the hepatic bud from the ventral aspect of the gut tube. When the duodenal loop rotates along with the stomach, the ventral bud comes to the right and the dorsal bud to the left. As a result of differential growth of the duodenal wall, the attachment of the ventral bud along with the bile duct shifts to the left side. The two buds fuse with each other and form the pancreas. The dorsal pancreatic bud forms the upper part of the head, neck, body and tail of pancreas. The ventral bud forms the lower part of head and the uncinate process. The ducts of the dorsal and ventral buds anastomose with each other. The main pancreatic duct is formed from the part of the dorsal pancreatic duct distal to the anastomosis, the anastomosis between the two ducts, and the ventral pancreatic duct proximal to the anastomosis. This duct, along with the bile duct, opens into the duodenum at the major duodenal papilla. The accessory pancreatic duct is formed from the proximal part of the dorsal pancreatic duct and opens into the duodenum at the minor duodenal papilla about 2 cm proximal to the major duodenal papilla.

SURFACES OF PANCREAS

The head and neck of the pancreas have anterior and posterior surfaces. The body of the pancreas has three surfaces (Fig. 18.20). The anterior surface faces anteriorly and upwards. The inferior surface faces downwards and somewhat forwards. The posterior surface faces backwards. The anterior and inferior surfaces meet at the anterior border. The anterior and posterior surfaces meet at the superior border and the inferior and posterior surfaces meet at the inferior border. A part of the body of the pancreas projects upwards beyond the lesser curvature

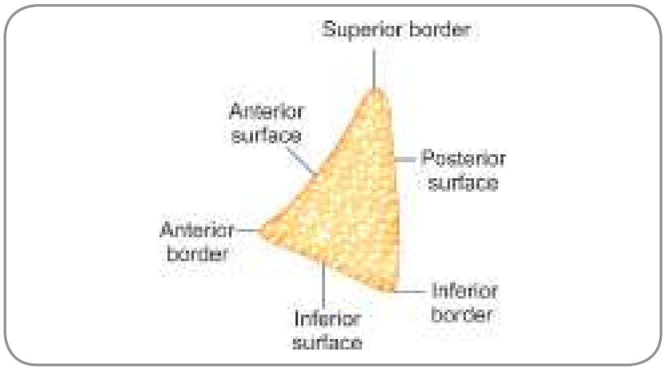


Fig. 18.20: Sagittal section through the body of the pancreas to show its surfaces and borders

of the stomach and comes in contact with the lesser omentum. This projection is called the ***tuber omentale*** (Fig. 18.19).

RELATIONS

The pancreas is placed in front of the inferior vena cava, the abdominal aorta and the left kidney. The head of the pancreas is placed in front of the inferior vena cava. The aorta is related to the right end of the body of the pancreas. Between the abdominal aorta and the left kidney, the body of the pancreas lies on the left crus of the diaphragm, the left suprarenal gland, and the left renal vessels. The superior mesenteric artery arises from the aorta deep to the pancreas. Lower down the artery lies in front of the uncinate process that intervenes between the superior mesenteric artery and the abdominal aorta (Fig. 18.19). Figure 18.21 shows the relationship of the pancreas to the superior mesenteric and splenic veins as they join to form the portal vein. The portal vein lies behind the neck of the pancreas, intervening between it and the inferior vena cava. The splenic vein lies behind the body of the pancreas, partially separating it from the other structures behind it.

The posterior edge of the greater omentum and the upper end of the transverse mesocolon are attached to the anterior aspect of the pancreas. On the body of the pancreas, the attachment is along the anterior border. The anterior surface of the body of the pancreas is covered by peritoneum which is continuous with the anterior of the two layers forming the greater omentum, and lies in the posterior wall of the lesser sac. The body of the pancreas (anterior surface) is related anteriorly to the stomach from which it is separated by the lesser sac. The inferior surface of the body of the pancreas is covered by peritoneum continuous with the posterior layer of the transverse mesocolon. It is related to the greater sac. The head of the pancreas is related anteriorly to the transverse colon. The neck of the pancreas is related anteriorly to the pylorus. The peritoneum lining the posterior aspect of the pylorus is reflected on to the anterior aspect of the neck of the pancreas. This is how the right boundary of the lesser sac of peritoneum is formed at this level. The gastroduodenal artery descends over the pancreas immediately in front of the neck. Superiorly, the head of the pancreas is related to the superior part of the duodenum. The body of the pancreas is related superiorly to the coeliac trunk (which lies just above the tuber omentale), the hepatic artery and the splenic artery. Inferiorly, the head of pancreas is related to the horizontal part of the duodenum. The inferior surface of the body of the pancreas is in the contact with the duodenojejunal flexure, the left colic flexure and the coils of jejunum.

DUCTS OF PANCREAS

Secretions of the pancreas are poured into the duodenum through two ducts (Fig. 18.22). The ***main pancreatic duct*** (duct of Wirsung) begins in the tail of the pancreas and passes to the right through the body. It increases in size as it runs through the body and receives several lobular ducts which join it almost at right angles forming

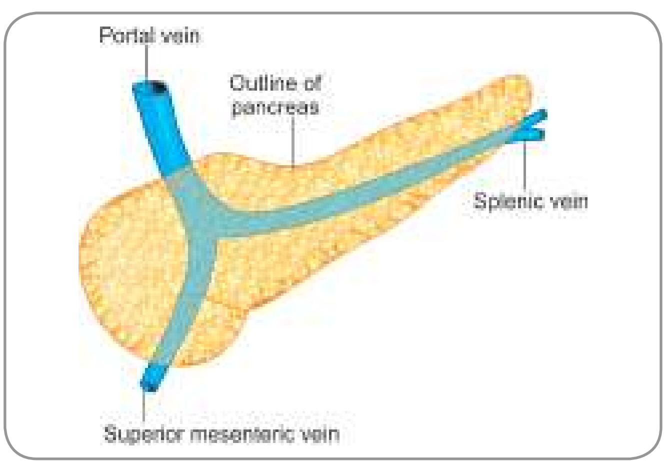


Fig. 18.21: Relationship of portal vein, superior mesenteric vein and splenic vein to the pancreas

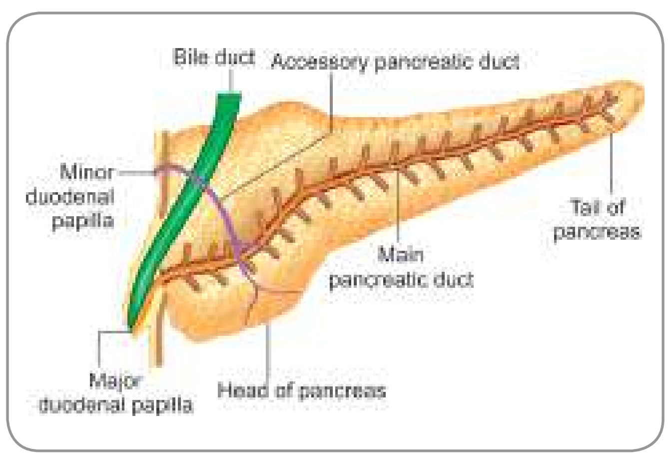


Fig. 18.22: Schematic diagram of the ducts of the pancreas

a "herring bone pattern". At the neck of the pancreas, it turns downwards and backwards and ends by coming in contact wth the bile duct just outside the duodenal wall. The walls of the bile and the main pancreatic ducts join each other here, but their lumina remain separate as the ducts descend through the muscle wall and submucosa of the duodenum (Fig. 18.17). Usually, the two ducts unite a short distance above the major duodenal papilla to form the hepatopancreatic ampulla. They may, however, have separate openings on the papilla. The terminal part of the main pancreatic duct is surrounded by the sphincter pancreaticus.

The ***accessory pancreatic duct*** (duct of Santorini) begins in the lower part of the head of the pancreas. It runs upwards crossing in front of the main duct and opens into the duodenum at the minor duodenal papilla (which lies a short distance above and in front of the major papilla). The main and accessory pancreatic ducts usually anastomose with each other. Occasionally, the duodenal end of the accessory duct may be blind. In that case, the duct drains into the duodenum through the anastomoses with the main duct. The accessory duct may be surrounded near its termination by a sphincter.

BLOOD SUPPLY, LYMPHATIC DRAINAGE AND NERVE SUPPLY OF PANCREAS

The pancreas is supplied by branches from the splenic artery and from the superior and inferior pancreaticoduodenal arteries.

The veins drain into the splenic, superior mesenteric and portal veins.

Lymphatics of the pancreas drain into the pancreaticosplenic nodes along the splenic artery and to the pancreaticoduodenal and coeliac nodes. Some vessels reach the superior mesenteric nodes.

The pancreas is innervated by autonomic nerves, both sympathetic and parasympathetic which travel to it through the plexus around the splenic artery.

Histology

Pancreas is both an exocrine and an endocrine gland. It produces both digestive enzymes and hormones. Pancreas is surrounded by a loose connective tissue capsule from which numerous septa pass into the parenchyma dividing into many lobules.

The ***exocrine pancreas*** comprises serous compound ***tubuloalveolar glands*** formed by pyramidal, serous acini. Serous cells are basophilic and contain ***zymogen granules*** at their apices. The secretions pour into the intercalated (intralobular) ducts. The ***intercalated ducts*** are invaginated into the secretory acinus and hence are not conspicuously seen in sections. On cross section of an acinus, the intercalated duct cells located inside the acinus appear to be centrally placed and hence are called centroacinar cells.

contd...

Histology *contd...*

Secretions from intercalated ducts drain into interlobular ducts and then finally drain into the main pancreatic ducts. Apart from the serous cells, pancreatic ***stellate cells*** are also seen. They are myofibroblast like cells encircling the base of the acinus.

The endocrine part of pancreas is formed by ***islets of Langerhans*** which are scattered among the serous acini of exocrine pancreas. They are arranged as anastomosing cords separated by fenestrated capillaries. Islets contain three types of cells, namely alpha cells, beta cells and delta cells which secrete glucagon, insulin and somatostatin respectively and are concerned with glucose metabolism.

Clinical Correlation

- ***Congenital malformations***
  - The pancreas is derived from ventral and dorsal buds which later fuse. Most of the organ is derived from the dorsal bud. The parts derived from the two buds may remain separate resulting in a ***divided pancreas***.
  - The parts of the pancreas arising from dorsal and ventral buds have independent ducts. The duct draining the part of the pancreas derived from the dorsal bud at first opens into the duodenum at the minor duodenal papilla. The duct of the ventral bud opens at the major duodenal papilla (along with the bile duct). When the dorsal and ventral parts fuse, their ducts anastomose. The distal part of the main pancreatic duct is derived from the (distal part of the) duct of the dorsal bud while its proximal part is derived from the duct of the ventral bud. The proximal part of the duct of the dorsal bud remains narrow and forms the accessory pancreatic duct. In some cases, the duct of the dorsal bud retains its embryonic form and in such cases, the main drainage of the pancreas is at the minor duodenal papilla. This condition is referred to as ***inversion of pancreatic ducts***.
  - Pancreatic tissue may develop all round the duodenum (***annular pancreas***) and can be a cause of obstruction to the duodenum.
  - ***Accessory pancreatic tissue*** may be present in the walls of the stomach, the duodenum, the jejunum, or the gallbladder. It can also be present in the spleen, and in the wall of a Meckel's diverticulum.
- ***Cystic fibrosis*** is a congenital (genetic) anomaly affecting the secretory elements of the pancreas.
- Pancreatic insufficiency leads to malabsorption.
- ***Congenital cysts*** may be present in the pancreas.
- The beta cells of pancreatic islets produce insulin, deficiency of which causes ***diabetes mellitus***.
- Inflammation of the pancreas is called ***pancreatitis***. It is often associated with collection of fluid in the lesser sac (***pseudopancreatic cyst***).
- A stricture may develop in the transverse colon where it overlies the pancreas.
- The pancreas may be eroded by an ulcer on the posterior wall of the stomach.

contd...

Clinical Correlation ***contd...***

- ***Tumours of pancreas:*** Carcinoma of the pancreas is relatively common. It can lead to biliary obstruction and jaundice. It can also cause obstruction at the pylorus or duodenum, and ascites by pressure on the portal vein. In some cases of carcinoma of the head of the pancreas, the organ is removed along with the duodenum (***pancreatico-duodenectomy***). Tumours arising from beta cells of pancreatic islets (***beta cell tumours*** or ***insulinoma***) can produce features of hyperinsulinism. A gastrin producing cell tumour can be responsible for repeated formation of peptic ulcers (***Zollinger-Ellison syndrome***).

SPLEEN

Other name: Lien.

The spleen (Greek.splen, Latin.lien=spleen) is a solid organ, irregularly oval in shape. It is about 12 cm long and 7 cm broad. It lies in the left hypochondrium, behind the stomach. Posteriorly, the spleen rests on the diaphragm opposite the ninth, tenth and eleventh ribs (Fig. 18.23). Its long axis corresponds to that of the tenth rib.

Development

Spleen develops as a collection of mesenchymal cells in the dorsal mesogastrium. The mesenchymal cells differentiate into lymphoblasts and other blood forming cells.

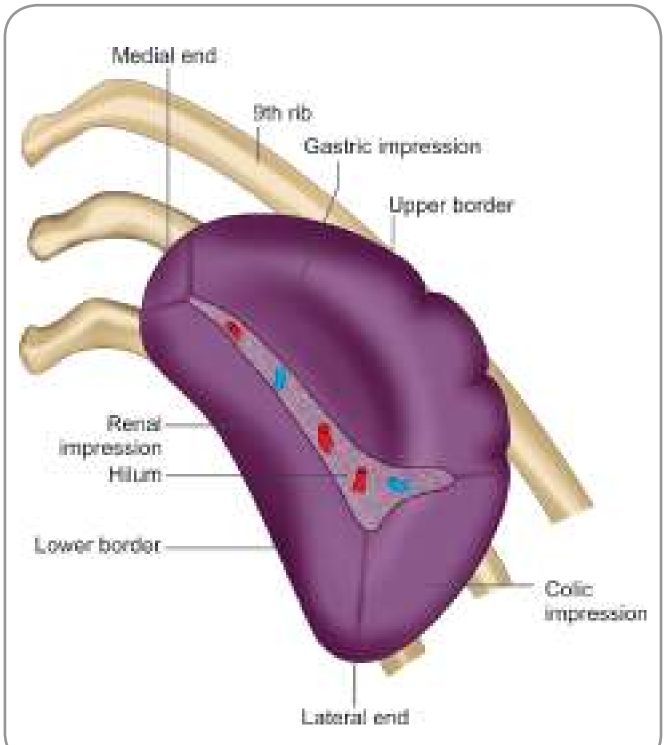


Fig. 18.23: Spleen as seen from the front

EXTERNAL FEATURES AND RELATIONS

The spleen has a ***medial end*** that is directed medially, upwards and backwards and a ***lateral end*** that is directed laterally, forwards and downwards. The medial end lies about 4 cm from the midline at the level of the spine of the tenth thoracic vertebra. The lateral end reaches up to the midaxillary line. The medial and lateral ends are joined by the ***upper (or anterior)*** and ***lower (or posterior) borders***. The upper border is sharp, while the lower is blunt. One or more notches are present on the upper border.

The spleen has a ***diaphragmatic surface*** and a ***visceral surface*** which are separated from each other by the upper and lower borders.

- The diaphragmatic surface is convex and is separated from the diaphragm only by peritoneum. The diaphragm separates this surface from the lower parts of the left lung and pleura. The lung is related only to the upper part of the spleen, but the pleura extends to its lower margin.
- The visceral surface of the spleen is shown in Figure 18.23. It is divided into three roughly triangular areas—the largest of these areas, placed anterosuperiorly, comes into contact with the stomach and is called the ***gastric impression***, the posteromedial part of the visceral surface comes into contact with the left kidney and is called the ***renal impression*** and the anteroinferior part comes in contact with the left colic flexure and is called the ***colic impression***.
- The region lying along the junction of these three impressions of the visceral surface is the ***hilum***. The spleen is penetrated here by branches of the splenic artery and vein. The tail of the pancreas comes in contact with the hilum of the spleen, near the colic impression.

PERITONEAL RELATIONS OF SPLEEN

The spleen develops in the upper part of the dorsal mesogastrium. In later life, this part of the mesogastrium is represented by the ***gastrosplenic ligament*** that passes from the greater curvature of the stomach to the hilum of the spleen. It is also represented by the ***lienorenal*** (or ***splenorenal) ligament*** that passes from the hilum to the front of the left kidney.

- The ***gastrosplenic ligament*** is made up of two layers—the anterior and posterior layers. The short gastric vessels and the left gastroepiploic branches of the splenic artery pass between these two layers.
- The ***lienorenal ligament*** is also made up of anterior and posterior layers. The splenic vessels and the tail of pancreas are present between these two layers.

When the peritoneum covering the posterior surface of the stomach is traced to the greater curvature, it becomes continuous with the anterior (or right) layer of the gastrosplenic ligament. At the hilum of the spleen, this layer becomes directly continuous with the right layer of the lienorenal ligament.

When the peritoneum covering the anterior surface of the stomach is traced to the greater curvature, it becomes continuous with the posterior (or left) layer of the gastrosplenic ligament. At the hilum of the spleen, this layer passes on to the surfaces of the spleen, covering (in that order) its gastric impression, the diaphragmatic surface and the renal impression, and then returns to the hilum. Here, it becomes continuous with the left layer of the lienorenal ligament. In this way, the spleen comes to be covered all around by peritoneum except at its hilum. The spleen is separated from the diaphragm, from the kidney and from the stomach, by a part of the greater sac of peritoneum. However, the tail of the pancreas passes in the interval between the two layers of the lienorenal ligament and comes into direct contact with splenic tissue.

BLOOD SUPPLY AND INNERVATION

The spleen is supplied by the splenic artery. The terminal part of the artery divides into a number of branches which pass through the lienorenal ligament to enter the hilum of the spleen. The splenic artery also gives off the short gastric and left gastroepiploic branches. These branches enter the gastrosplenic ligament and thus reach the stomach.

The splenic vein accompanies the artery and ends in the portal vein.

The spleen receives autonomic nerves which reach it by running along the plexus surrounding the splenic artery.

Histology

It is the largest lymphoid organ of the body. It is enclosed by a capsule from which trabeculae are given off into the substance of the organ. Parenchyma of the spleen shows two distinct areas—***white pulp*** and ***red pulp***.

1. ***White pulp*** is the rounded whitish grey area and is made of lymphoid follicles. The differentiating feature of white pulp, from other lymphoid tissue like lymph node, is that within the lymphoid follicle (in spleen), an eccentrically situated arteriole is present. This arteriole is a branch of the splenic artery and is surrounded by the ***periarterial lymphatic sheath (PALS)*** (chiefly made up of T lymphocytes). On exposure to antigens, the lymphatic nodules become enlarged and are called splenic nodules or ***Malpighian corpuscles***.

contd…

Histology *contd…*

2. ***Red pulp*** consists of splenic sinuses separated by ***splenic cords (Billroth's cords)***. Splenic cords are made up of a spongy network of reticular fibres infiltrated with reticular cells, lymphocytes, plasma cells, macrophages and all elements of circulating blood. ***Splenic venous sinuses*** are lined with fenestrated flattened endothelial cells ***(Stave cells)*** through which flexible red blood cells pass easily to and from the cords and sinuses.

The arteriole leaves the lymphatic sheath of white pulp and enters the red pulp where it divides to form straight ***penicillar arterioles*** which continue as arterial capillaries. Two types of circulation are seen within the splenic red pulp. Blood from some of the arterial capillaries flows directly into the venous sinuses and is a ***closed circulation***. Blood from some other arterial capillaries opens into the splenic cords through the minute slits in their walls before entering the sinuses; this is an ***open circulation***. Non flexible old erythrocytes are retained in cords and engulfed by macrophages.

Marginal zone is the zone between white and red pulps and is an immunologically active zone.

Clinical Correlation

- ***Congenital malformations:***
  - The spleen may show lobulation.
  - Accessory splenula may be present in structures near the organ including the gastrosplenic and lienorenal ligaments, the hilum of the spleen itself, the pancreas and along the splenic artery. Such accessory splenula have been variedly called the splenculi, spleneoli, lienculi, liena succenturiati and liena accessorii.
  - Rarely, the spleen may be absent.
  - Congenital cysts may be present in the spleen.
- Enlargement of the spleen (***splenomegaly***) occurs in many diseases. In India, the most common cause of enlargement is malaria. Enlargement also takes place in portal hypertension. A normal spleen does not extend anteriorly beyond the midaxillary line. When enlarged considerably (to almost twice its normal size), the spleen projects from under the costal margin and can be felt on palpation of the abdomen.
- Surgical removal of the spleen is called ***splenectomy***. Because of the close relationship of the tail of the pancreas to the hilum of the spleen, the former may be injured during splenectomy.
- The spleen can be ruptured as a result of trauma (especially when enlarged). This can lead to death from internal haemorrhage. Immediate splenectomy may save the patient.
- Radio-opaque dyes may be introduced into the portal venous system through a needle introduced into the spleen (***splenovenography*** or ***splenoportography***). The technique has now been largely replaced by coeliac angiography.

Multiple Choice Questions

1. The following ligaments form boundaries of the bare area of liver except:
   a. Superior layer of coronary ligament
   b. Inferior layer of coronary ligament
   c. Right triangular ligament
   d. Left triangular ligament
2. The boundaries of Calot's triangle include all structures except:
   a. Visceral surface of liver
   b. Cystic duct
   c. Portal vein
   d. Common hepatic duct
3. The tail of pancreas is one of the contents of which ligament?
   a. Gastrosplenic ligament
   b. Lienorenal ligament
   c. Phrenicocolic ligament
   d. Gastrophrenic ligament
4. Uncinate process of pancreas is anteriorly related to:
   a. Superior mesenteric vessels
   b. Inferior mesenteric vessels
   c. Abdominal aorta
   d. Portal vein
5. The duct of Wirsung is the other name for:
   a. Common bile duct
   b. Hepatic duct
   c. Main pancreatic duct
   d. Accessory pancreatic duct

ANSWERS

1. d **2.** c **3.** b **4.** a **5.** c

Clinical Problem-solving

Case Study 1: A 45-year-old woman complains of pain in the right hypochondrium. On and off, she also has pain over the right shoulder. The pain seems to travel from the right hypochondrium to the right shoulder.

- What condition, do you think, is the woman suffering from?
- What sign can be elicited in such a condition and where?

Case Study 2: A 45-year-old man complains of non-specific pain in the abdomen. On examination, it is found that he has splenomegaly and caput medusa.

- With your anatomy knowledge, can you guess the condition he is suffering from?
- Why is there a splenomegaly in this condition?

(For solutions see Appendix)

Chapter 19

Blood Vessels of Stomach, Intestines, Liver, Pancreas and Spleen

Frequently Asked Questions

- Write notes on: (a) Coeliac trunk, (b) Hepatic artery, (c) Inferior mesenteric artery and its branches.
- Discuss the hepatic portal venous system in detail. Add a note on the portocaval anastomosis.
- Write briefly on: (a) Splenic artery, (b) Pancreaticoduodenal arteries, (c) Formation of portal vein.

INTRODUCTION

The arteries which supply the stomach, the intestines, the liver, the pancreas and the spleen are the ***ventral branches*** of the abdominal aorta. These are: the ***coeliac trunk,*** the ***superior mesenteric artery and*** the ***inferior mesenteric artery***. The veins draining these organs do not drain directly into the systemic circulation; they first drain into the portal vein through which blood reaches the liver. After passing through the sinusoids of the liver, the blood reaches the inferior vena cava through the hepatic veins.

COELIAC TRUNK AND ITS BRANCHES

The coeliac trunk arises from the front of the uppermost part of the abdominal aorta just below the aortic opening in the diaphragm at the level of 12th thoracic vertebra. The trunk is only about one centimeter long. It passes forwards and terminates by dividing into three branches: These are: the left gastric artery, the hepatic artery and the splenic artery. The coeliac trunk is covered in front by the peritoneum lining the posterior wall of the lesser sac. It is related above to the diaphragm. The caudate process of the liver lies above and to its right. The stomach lies below and to its left. The pancreas and splenic vein lie below it. On either side, the coeliac trunk is related to the corresponding crus of the diaphragm and to the coeliac ganglion. The coeliac trunk is surrounded by branches of the ***coeliac plexus*** of nerves.

Left Gastric Artery

The left gastric artery arises from the coeliac trunk and passes upwards and to the left ('a' in Fig. 19.1) on the posterior abdominal wall (formed here by the diaphragm). Reaching near the cardiac end of the stomach the artery turns forwards and passes from the diaphragm to the lesser curvature of the stomach ('b' in Fig. 19.1). The artery then runs to the right along the lesser curvature of the stomach ('c' in Fig. 19.1) between the two layers of the lesser omentum. It ends by anastomosing with the right gastric artery.The left gastric artery gives branches to the oesophagus and to both surfaces of the stomach. Some oesophageal branches pass through the oesophageal hiatus of the diaphragm and anastomose with branches to the oesophagus from the thoracic aorta.

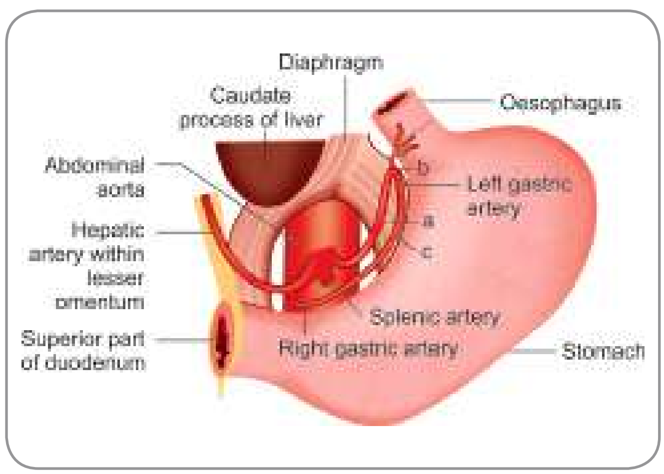


Fig. 19.1: Scheme to show course of the left and right gastric arteries

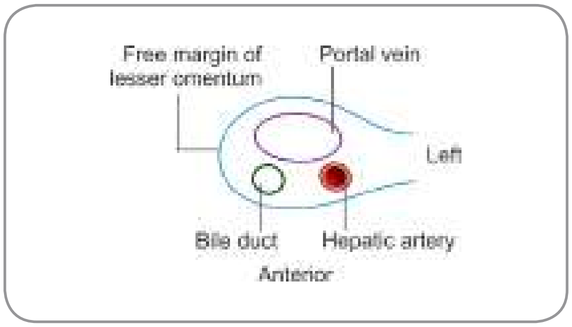


Fig. 19.2: Structures in the free margin of the lesser omentum

Hepatic Artery

The hepatic artery first runs to the right and somewhat downwards on the posterior abdominal wall (Fig. 19.1) to reach the superior part of the duodenum. It then passes forwards above the first part of duodenum and below the epiploic foramen. Finally, it turns upwards to enter the free margin of the lesser omentum. It now lies anterior to the foramen epiploicum. Ascending in the lesser omentum, it reaches the porta hepatis where it divides into right and left branches for the corresponding lobes of the liver. Within the free margin of the lesser omentum, the artery lies in front of the portal vein with the bile duct to its right (Fig. 19.2). The hepatic artery is further subdivided into the common hepatic artery (extending from the coeliac trunk to the origin of the gastroduodenal artery) and the hepatic artery proper (from the origin of the gastroduodenal artery to its point of bifurcation into the right and left branches near the porta hepatis). Branches of the hepatic artery are the right gastric artery, the gastroduodenal artery, the supraduodenal artery (sometimes), the cystic artery and the terminal hepatic branches (Fig. 19.3).

Right Gastric Artery

The right gastric artery arises from the hepatic artery as the latter lies above the 1st part of duodenum. It passes to the left along the lesser curvature of the stomach between the two layers of the lesser omentum to anastomose with the left gastric artery.

Gastroduodenal Artery

The gastroduodenal artery also arises from the hepatic artery as the latter lies above the duodenum (Fig. 19.3). It descends ***behind*** the superior part of the duodenum. Here it lies in front of the neck of the pancreas and to the left of the bile duct. It ends by dividing into the right gastroepiploic and superior pancreaticoduodenal arteries (anterior and posterior).The gastroduodenal artery also gives off small branches to the stomach, the pancreas, and the duodenum. It sometimes gives off the supraduodenal artery.

Right Gastroepiploic Artery

The right gastroepiploic artery (Fig. 19.3) runs to the right along the greater curvature of the stomach (between the two layers of the greater omentum). It ends by anastomosing with the left gastroepiploic artery (a branch of the splenic artery). The right gastroepiploic artery gives branches to the stomach and to the greater omentum.

Superior Pancreaticoduodenal Arteries

There are two superior pancreaticoduodenal arteries: anterior and posterior. They descend on the anterior and posterior aspects of the junction of the second part of duodenum with the pancreas respectively. They supply the pancreas, and the duodenum up to the level of the major duodenal papilla. Here, they anastomose with the branches of the inferior pancreaticoduodenal artery (branch of superior mesenteric artery). The part of the duodenum above the major duodenal papilla is a derivative of the foregut. It is, therefore, supplied by branches of the coeliac trunk, which is the artery of the foregut. The rest of the duodenum is derived from the midgut, the artery of which is the superior mesenteric artery. The part of the

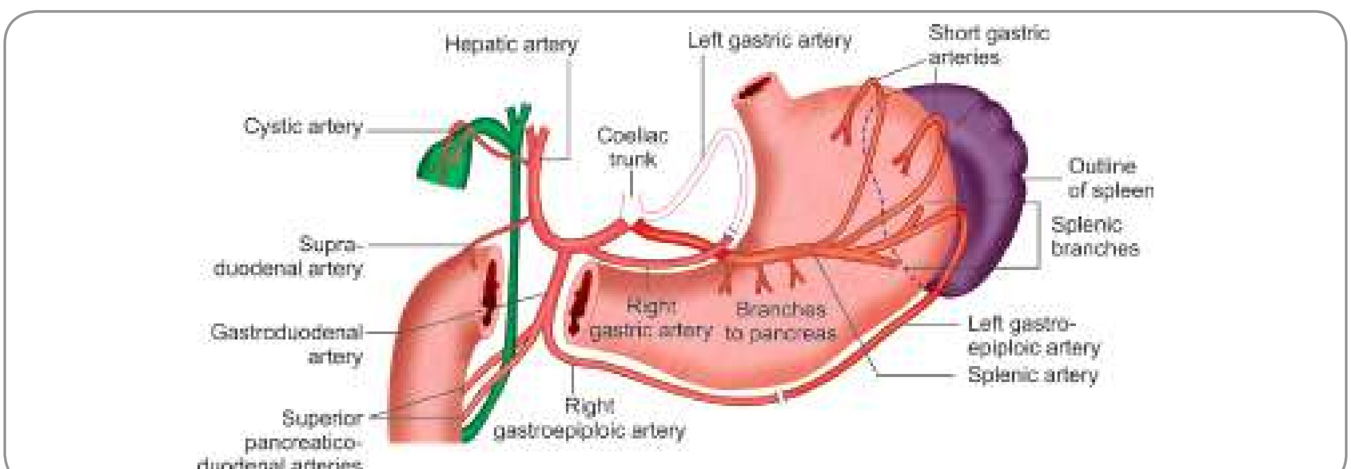


Fig. 19.3: Scheme to show the distribution of the hepatic and splenic arteries

duodenum below the major duodenal papilla is, therefore, supplied by the branches of the superior mesenteric artery.

Supraduodenal Artery

The supraduodenal artery may arise from the gastroduodenal artery (Fig. 19.3) or directly from the hepatic artery. It supplies the superior part of the duodenum.

Cystic Artery

The cystic artery (Fig. 19.3) usually arises from the right branch of the hepatic artery. It passes to the right behind the hepatic and cystic ducts to reach the gall bladder that it supplies. It also gives branches to the hepatic ducts and the upper part of the bile duct. Its origin and course are highly variable.

Hepatic Branches

The right and left hepatic branches enter the corresponding lobe of the liver and divide within them in a fairly constant manner. As a result of this fact, the liver can be divided into a number of arterial segments.

Splenic Artery

The splenic artery arises from the coeliac trunk. It has a tortuous course. Its initial part runs to the left on the posterior abdominal wall along the upper border of the pancreas (Fig. 19.3). Here, it is separated from the stomach by the lesser sac of peritoneum (Fig. 19.4). Reaching the front of the left kidney the artery passes into the lienorenal ligament to reach the hilum of the spleen where it divides into two or three branches which enter the hilum of spleen.

Several other branches are also given out from the splenic artery. These are

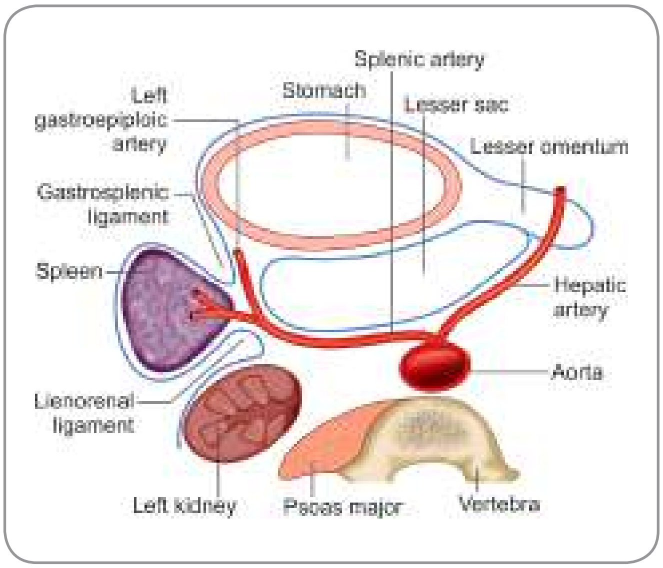


Fig. 19.4: Schematic transverse section to show the course of the splenic artery

Pancreatic branches: Which supply the neck, body and tail of pancreas; most important of these are the Arteria pancreatica magna and the Arteria caudae pancreatis which take part in an anastomosis around the pancreas, further contributed to by the arteria pancreatica dorsalis.

Short gastric arteries–usually 5 in number: Which arise near the hilum of the spleen and pass through the gastrosplenic ligament to supply the fundus of the stomach.

Left gastroepiploic artery: Which arises near the hilum of the spleen and passes downwards, forwards and to the right through the gastrosplenic ligament to reach the greater curvature of the stomach; it gives branches to the stomach and to the greater omentum and ends by anastomosing with the right gastroepiploic artery.

Splenic branches: Which enter into the spleen further divide and give out the segmental arteries of the spleen. Each segmental artery supplies a segment of the spleen. There is practically no arterial collateral circulation between the segments. However, venous collateral circulation does exist.

It can be seen clearly that, apart from supplying the liver, pancreas and spleen, the coeliac trunk supplies the infradiaphragmatic part of the gut up to the middle of the descending part of the duodenum (up to the major duodenal papilla). This part of the gut is derived from the embryonic foregut. The coeliac trunk is, therefore, described as the ***artery of the foregut*** (Fig. 19.5).

SUPERIOR MESENTERIC ARTERY

The superior mesenteric artery is the artery of the midgut. Its area of supply extends cranially up to the middle of the descending part of the duodenum, and caudally to the junction of the right two-thirds and left one-third of the transverse colon. The artery arises from the front of the abdominal aorta a little below the coeliac trunk, at the level of L1 vertebra and runs downwards and forwards. Its initial part lies over the posterior abdominal wall. The artery then crosses in front of the horizontal part of the duodenum to enter the root of the mesentery. Passing through the root of the mesentery it runs downwards and to the right to reach the ileocaecal junction. The artery gives off numerous branches to the gut.

Relations of Superior Mesenteric Artery

The initial part of the artery lies over the posterior abdominal wall. This part lies deep to the pancreas and the splenic vein, and superficial to the left renal vein that separates it from the front of the aorta. The uncinate process of the pancreas also lies deep to it. The next part of the artery passes in front of the horizontal part of the duodenum. It then passes into the root of the mesentery.

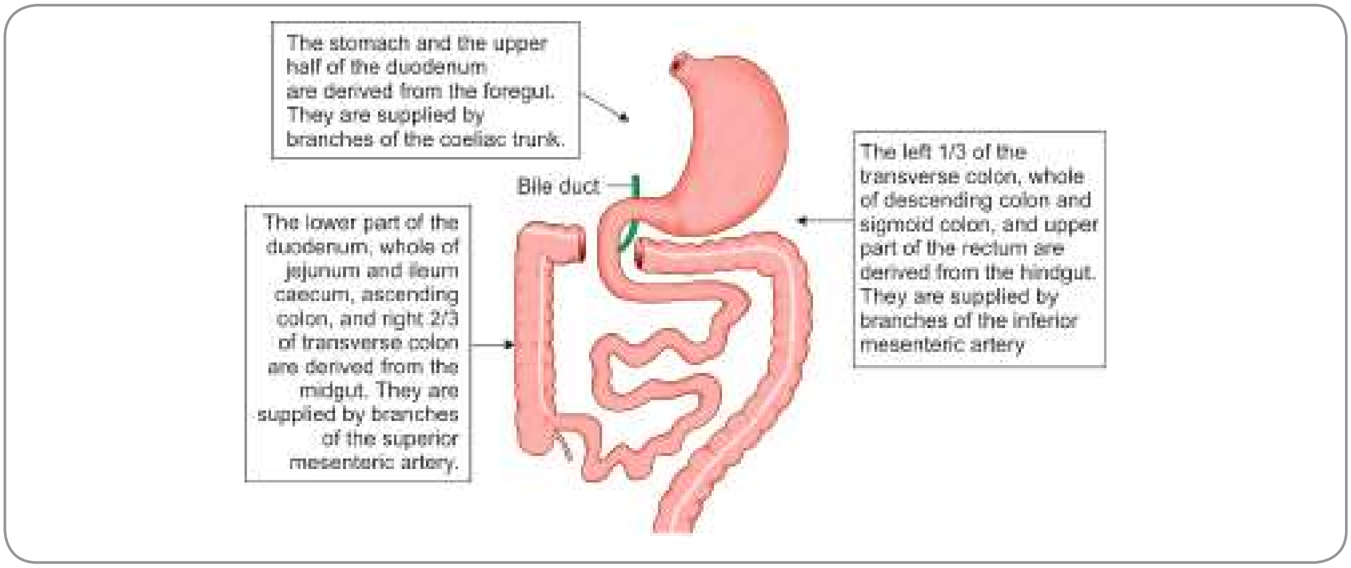


Fig. 19.5: Scheme to show parts of the gut supplied by the coeliac trunk, the superior mesenteric and inferior mesenteric arteries

This part of the artery crosses inferior vena cava, right ureter and right psoas major. The artery is accompanied by the superior mesenteric vein, which lies to its right side, and by a plexus of nerves.

Branches of Superior Mesenteric Artery

- ***Inferior pancreaticoduodenal artery*** is the first branch. It divides into anterior and posterior branches which run upwards on the corresponding aspects of the head of the pancreas. They supply the pancreas and duodenum and anastomose with the corresponding branches of the superior pancreaticoduodenal arteries.
- ***Branches to the jejunum and ileum*** are many. They arise from the left side of the superior mesenteric artery and pass through the mesentery to reach the gut. The branches anastomose with each other to form a series of arches from which numerous straight arteries arise to supply the gut (Fig. 19.6).
- ***Middle colic artery*** arises from the right side of the superior mesenteric artery just below the duodenum. It runs downwards into the transverse mesocolon to reach the transverse colon. Its branches anastomose (on the right side) with those of the right colic artery, and (on the left side) with those of the left colic artery (a branch of the inferior mesenteric artery). They supply the right two-thirds of the transverse colon.
- ***Right colic artery*** arises from the right side of the superior mesenteric artery at about its middle. It passes to the right (on the posterior abdominal wall) to reach the ascending colon. It terminates by dividing into descending and ascending branches which anastomose with the ileocolic and middle colic arteries, respectively. The artery supplies the upper two-thirds of the ascending colon.
- ***Ileocolic artery*** arises from the right side of the lower part of the superior mesenteric artery. It runs on the posterior abdominal wall a little above the parent vessel. It ends by dividing into superior and inferior branches. The inferior branch anastomoses with the terminal part of the superior mesenteric artery. The superior branch anastomoses with the right colic artery. The inferior branch of ileocolic artery also gives out following branches—an ascending branch which supplies the lower part of ascending colon; the anterior and posterior caecal branches which supply the anterior and posterior aspects of caecum; the appendicular artery which supplies the vermiform appendix and the

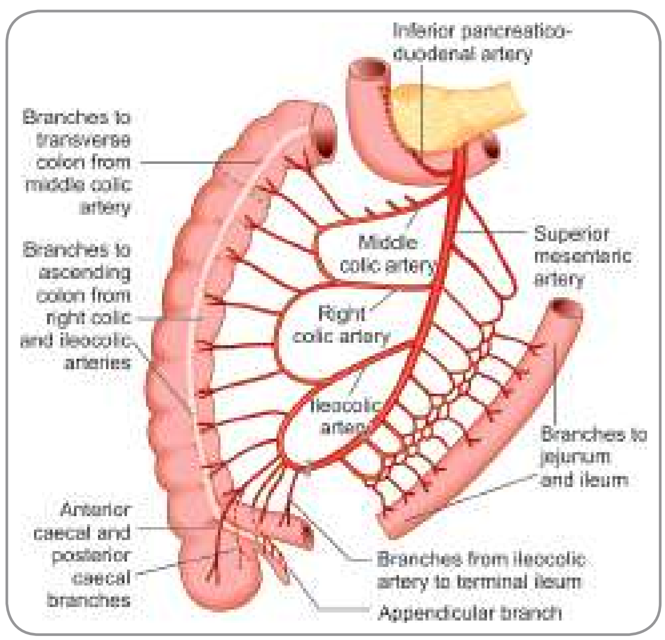


Fig. 19.6: Distribution of superior mesenteric artery

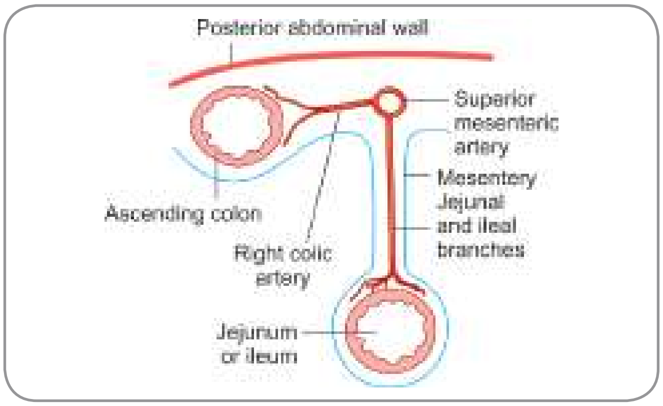


Fig. 19.7: Scheme to show that some branches of the superior mesenteric artery are retroperitoneal while some pass through folds of peritoneum

ileal branch that anastomoses with the termination of the superior mesenteric artery.Thus, the ileocolic artery supplies several parts of the gut including the terminal part of ileum, caecum, appendix and the lower one-third of ascending colon (Fig. 19.6).

Note: The inferior pancreaticoduodenal, right colic and ileocolic branches have a retroperitoneal course (Fig. 19.7). The middle colic artery runs in the transverse mesocolon. The jejunal and ileal branches traverse the mesentery of the small intestine.

INFERIOR MESENTERIC ARTERY

The distribution of inferior mesenteric artery is shown in Figure 19.8.

The inferior mesenteric artery supplies the hindgut. Its area of supply extends from the junction of the right two-thirds and left one-third of the transverse colon to the rectum. The artery arises from the front of the aorta about 3 cm above its bifurcation. It runs downwards (and slightly to the left) over the posterior abdominal wall. Beginning over the middle of the aorta, it gradually crosses to its left side. It then crosses the left common iliac artery below which its continuation is called the ***superior rectal artery***.

The branches given off by the inferior mesenteric artery are the left colic, sigmoid and superior rectal arteries.

- The ***left colic artery*** runs upwards and to the left behind the peritoneum of the posterior abdominal wall and divides into ascending and descending branches. The ascending branch enters the transverse mesocolon. Here, it anastomoses with the middle colic branch of the superior mesenteric artery. The descending branch anastomoses with the highest sigmoid artery. The various branches of the left colic artery subdivide and form arcades from which straight arteries arise to supply the left one-third of the transverse colon and most of the descending colon.
- The ***sigmoid branches*** enter the pelvic mesocolon to reach the sigmoid colon. They anastomose above with the descending branch of left colic artery and below with the superior rectal artery and thus supply the lower part of the descending colon.

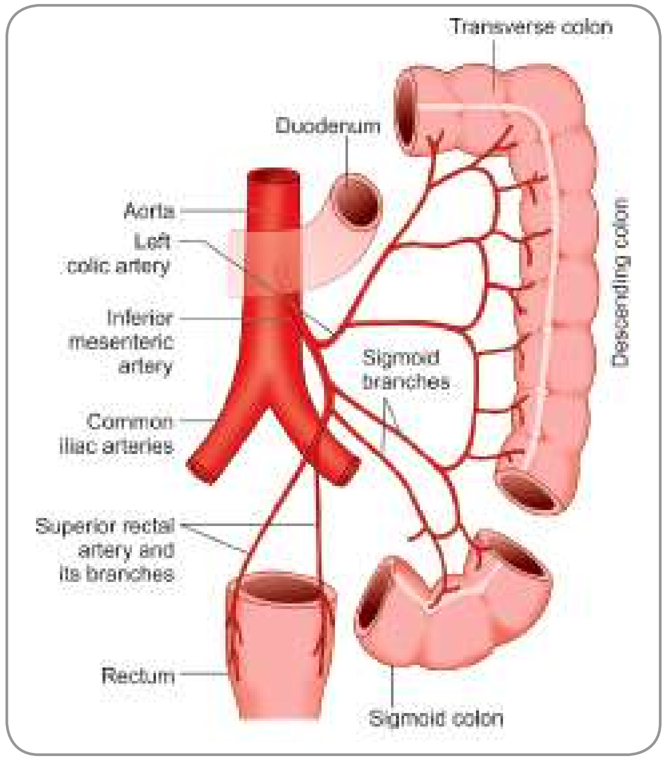


Fig. 19.8: Distribution of inferior mesenteric artery

Superior Rectal Artery

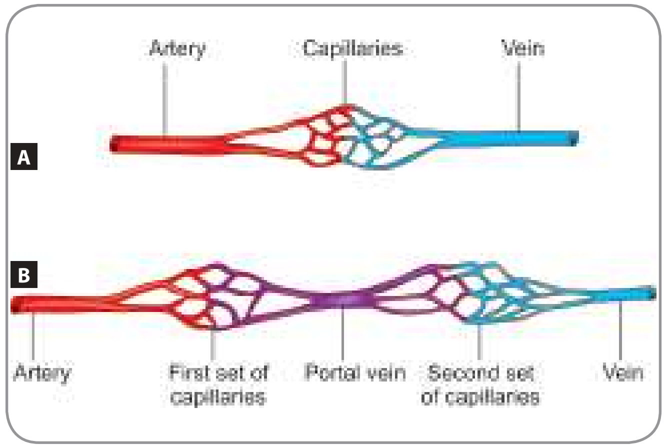
The superior rectal artery is a continuation of the inferior mesenteric artery into the true pelvis. It runs across the left common iliac artery and vein to reach the rectum. Opposite the third sacral vertebra, it divides into two main branches, one of which descends on either side of the rectum and supplies it. Their area of supply extends up to the sphincter ani internus. They anastomose with the middle rectal artery (branch of the internal iliac) and with the inferior rectal artery (branch of the internal pudendal artery).

- ***Marginal artery of Drummond:*** This is the name given to the vessel that lies close to the wall of the large intestine and runs parallel to the wall within the folds of the mesentery. It is formed by the arterial arcades arising from the ileocolic, right colic, middle colic and left colic arteries. The sigmoid colon does not have any significant marginal artery. Vasa recta and vasa brevia arise from this anastomosis and supply the colon. The anastomosis may hypertrophy when one of the major vessels is compromised and then may provide an efficient collateral circulation.
- ***Arc of riolan:*** This is the name given to a direct arterial anastomosis that sometimes exists between the right side of the transverse colon and the upper part of the descending colon. A large collateral branch of the middle colic artery in the transverse mesocolon anastomoses

with an ascending branch of the left colic artery near the root of mesentery. A direct communication between the superior and the inferior mesenteric territories is thus established.

HEPATIC PORTAL SYSTEM

Normally the arteries supplying an organ end in a set of capillaries from which blood is collected by veins that carry it to the heart (Fig. 19.9A). In some cases, however, the veins from an organ enter another organ where they divide into a second set of capillaries (or sinusoids). Such an arrangement is called a ***portal system*** (Fig. 19.9B). The best example of a portal system is the hepatic portal system. The arteries supplying the abdominal part of the gastrointestinal tract (excluding the lower part of the anal canal) break up into capillaries in its wall (first set). Veins draining these capillaries ultimately end in the portal vein that enters the liver. Within the liver, the portal vein divides into sinusoids (that is, second set of capillaries). This blood is returned to the heart through the hepatic veins and the inferior vena cava.



Figs 19.9A and B: Scheme to compare **A.** Systemic and **B.** Portal circulations

Hepatic Portal Vein

The portal vein (or the vena portae), about 8 cm long is formed by the union of the superior mesenteric and splenic veins. The point of union lies at the level of the second lumbar vertebra, behind the neck of the pancreas.

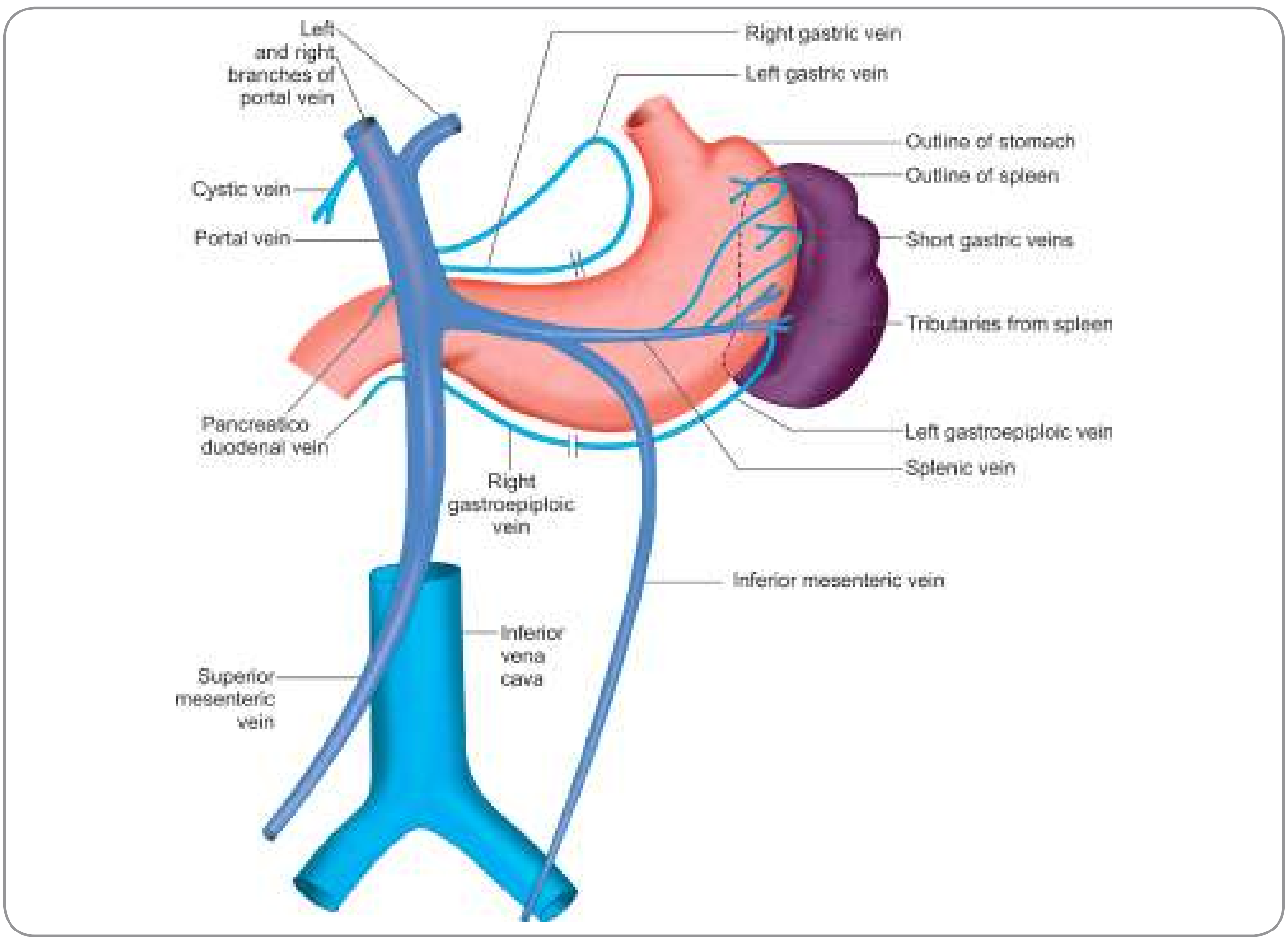


Fig. 19.10: Scheme to show the tributaries of the portal vein

The vein passes upwards and to the right to reach the porta hepatis where it ends by dividing into the right and left branches. These branches enter the substance of the liver.

Relations of Portal Vein

The portal vein has important relations (Figs 19.11 and 19.12). Its lower part is placed on the posterior abdominal wall, in front of the inferior vena cava. This part lies behind the neck of the pancreas, and higher up behind the superior part of the duodenum. Above the duodenum, the vein enters the free margin of the lesser omentum. It is now separated from the inferior vena cava by the epiploic foramen (Fig. 19.11). As it enters the porta hepatis, it is separated from the inferior vena cava by the caudate process of the liver.

The following additional relations may also be seen. The vein is separated from the superior part of duodenum by the bile duct and the gastroduodenal artery. Within the free margin of the lesser omentum, the bile duct and the hepatic artery are in front of it. The bile duct is to the right of the artery.The shorter and wider right branch of the portal vein receives the cystic vein from the gall bladder. It is distributed to the right lobe of the liver. The longer and narrower left branch of the portal vein is joined by the ligamentum teres (representing the obliterated left umbilical vein). It is connected to the inferior vena cava by the ligamentum venosum (obliterated ductus venosus).

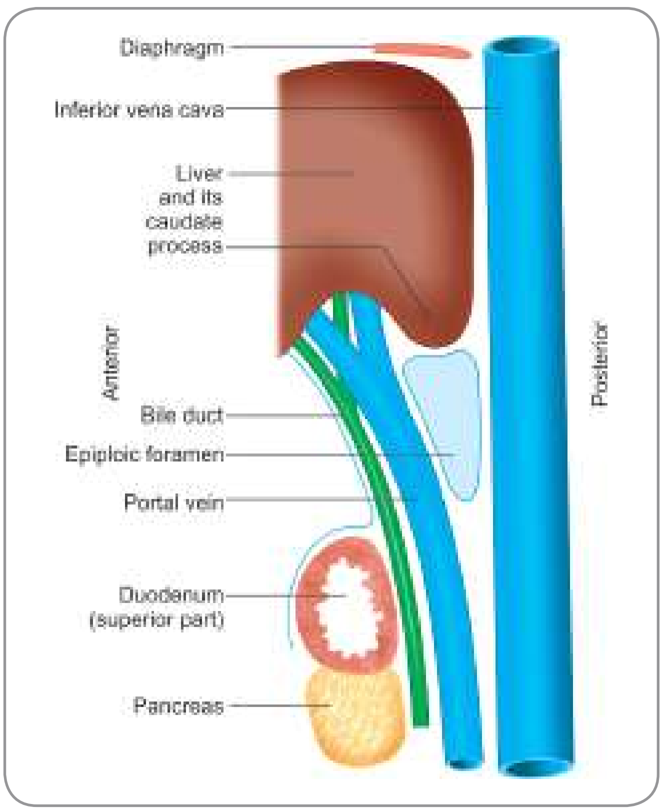


Fig. 19.11: Scheme to show some relations of the portal vein (schematic parasagittal section)

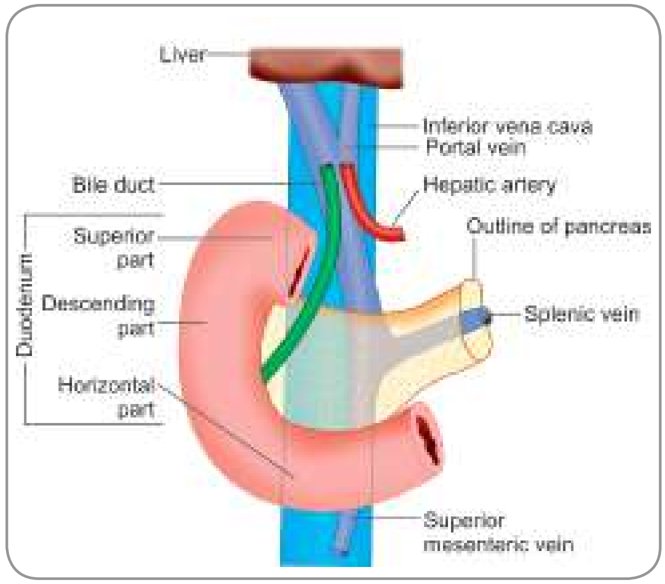


Fig. 19.12: Some relations of the portal vein as seen from the front

The left branch is distributed to the left lobe of the liver and also to the caudate and quadrate lobes.

Tributaries of Portal Vein

Splenic Vein

Emerging from the hilum of the spleen, the splenic vein runs through the lienorenal ligament and then runs across the posterior abdominal wall, posterior to the body of the pancreas, and anterior to the left kidney. It ends behind the neck of the pancreas by uniting with the superior mesenteric vein to form the portal vein (Fig. 19.10).

Tributaries of Splenic Vein

- Short gastric veins drain the fundus and the greater curvature of stomach and pass through the gastro-splenic ligament;
- Left gastro-epiploic vein drains both surfaces of stomach and greater omentum and passes between the anterior two layers of the greater omentum;
- Pancreatic veins drain the body and tail of pancreas;
- Inferior mesenteric vein drains the rectum, sigmoid colon and descending colon; it begins in rectum as the superior rectal vein, crosses the left common iliac vessels to continue upwards as the inferior mesenteric vein; it receives the sigmoid veins and the left colic vein.

Superior Mesenteric Vein

The superior mesenteric vein drains blood from the small intestine, caecum, ascending colon and transverse colon. It passes through the mesentery of small intestine. As it ascends upwards it passes in front of inferior vena cava, third part of duodenum and uncinate process of pancreas. It ends behind the neck of the pancreas by uniting with the splenic vein to form the portal vein.

Tributaries of Superior Mesenteric Vein

- Jejunal, ileal, ileocolic, right colic and middle colic veins(corresponding to the branches of the superior mesenteric artery)
- Right gastro-epiploic vein drains part of the stomach and the greater omentum and passes between the anterior two layers of the greater omentum.
- Pancreatico-duodenal veins

Left Gastric Vein

Left gastric vein receives oesophageal veins from the cardiac end of stomach.

Right Gastric Vein

Right gastric vein receives pre-pyloric vein which runs in front of pylorus.

Cystic Veins

Cystic veins from the gall bladder drain into the right branch of the portal vein.

Para-umbilical Veins

Para-umbilical veins run along the ligamentum teres in the falciform ligament. It drains into the left branch of the portal vein.

Hepatic Veins

The hepatic veins are the terminal parts of an elaborate venous tree that permeates the liver. The hepatic veins emerge from the liver tissue which is in close contact with the upper part of the inferior vena cava and immediately enter the vena cava.

Clinical Correlation

Portosystemic Anastomosis and Associated Conditions

At certain sites, veins of the portal system anastomose with the systemic veins. Normally, the flow through these communications is insignificant, but when there is obstruction to flow of blood in the portal circulation (e.g., by cirrhosis of the liver), these communications enlarge and serve as alternative channels of flow. It is important to know the sites of such communications as these enlarged veins are of clinical significance.

The most important sites of communication (portosystemic or portocaval anastomoses) are the

- ***Region of the umbilicus:*** Which is drained by the systemic veins of the anterior abdominal wall; some small paraumbilical veins pass from the umbilicus through the falciform ligament to reach the liver where they anastomose with the left branch of the portal vein. In portal obstruction, blood flows through the paraumbilical veins into the systemic veins at the umbilicus. The superficial veins of the abdominal wall enlarge and are seen radiating from the umbilicus. This appearance is called the ***caput medusae.***
- ***Lower end of the oesophagus:*** Which drains partly into the left gastric vein (portal) and partly into the accessory hemiazygos vein (systemic). In portal obstruction, the communications between these two sets of veins enlarge to form swellings called ***oesophageal varices***. Such varices may not be confined to the lower end of the oesophagus but may extend for some distance into the stomach. Rupture of these varices can cause serious bleeding. Oesophageal varices can be demonstrated radiologically (by barium swallow) and can be directly seen through oesophagoscopy.
- ***Wall of the anal canal:*** Which drains partly into the superior rectal vein (portal) and partly into the middle and inferior rectal veins (systemic). Enlargement of the communications between these veins can be an important factor predisposing to the formation of ***haemorrhoids*** or ***piles***.

Other sites of communication between systemic and portal veins are seen in relation to the ***bare area of the liver*** (where hepatic veins anastomose with phrenic and intercostal veins), the ***posterior abdominal wall*** where veins draining the parts of the gut which are retroperitoneal (i.e., the duodenum, the ascending colon and descending colon) anastomose with systemic veins of the posterior abdominal wall (renal, lumbar and phrenic veins).

In foetal life, most of the blood in the portal vein is short circuited to the inferior vena cava through the ductus venosus. This channel may sometimes remain patent after birth forming a natural portocaval shunt.

Portal Hypertension

Portosystemic anastomoses undergo enlargement when there is obstruction to flow of blood in the portal vein. Such obstruction can be caused by cirrhosis of liver (a disease in which liver tissue undergoes extensive fibrosis). It can also be caused by thrombosis in the portal vein. Obstruction leads to increased pressure in the portal circulation, the pressure rising from a normal of about 10 mmHg to over 40 mmHg. Surgical treatment of portal hypertension aims at creating a shunt between the portal vein (or superior mesenteric vein) and the inferior vena cava. Alternatively, the splenic vein is cut and joined to the left renal vein.

Multiple Choice Questions

1. The ventral branches of the abdominal aorta include:
   a. The coeliac trunk, the gastroduodenal artery and the hepatic artery
   b. The coeliac trunk, the superior mesenteric and inferior mesenteric arteries
   c. The superior mesenteric artery, the inferior mesenteric artery and supraduodenal artery
   d. The coeliac trunk, the splenic artery and the inferior mesenteric artery
2. The largest branch of the coeliac trunk is the:
   a. Left gastric artery
   b. Hepatic artery
   c. Splenic artery
   d. Supraduodenal artery
3. The continuation of the inferior mesenteric artery into the true pelvis is the:
   a. Superior rectal artery
   b. Inferior rectal artery
   c. Left colic artery
   d. Artery of Drummond
4. The formation of the portal vein is at the level of:
   a. The L2 vertebra
   b. The L4 vertebra
   c. The T12 vertebra
   d. The L1 vertebra
5. The cystic vein drains into the:
   a. Right branch of portal vein
   b. Left branch of portal vein
   c. Stem of portal vein
   d. Superior mesenteric vein

ANSWERS

1. b **2.** c **3.** a **4.** a **5.** a

Clinical Problem-solving

Case Study 1: A 45-year-old man presented with caput medusae and oesophageal varices.

- What is your probable diagnosis in this case?
- Why are the above mentioned two features seen?
- What are the other features likely to be noted?

(For solutions see Appendix).

Chapter 20

Kidney, Ureter and Suprarenal Gland

Frequently Asked Questions

- Discuss the right kidney with regard to its location, relations, blood supply and internal structure. Add a note on its development.
- Write notes on: (a) Renal fascia, (b) Anterior relations of left kidney, (c) Renal segments, (d) Morris parallelogram, (e) Suprarenal glands.
- Write briefly on: (a) Ureteric constriction points, (b) Renal angle.

The organs of the body which are concerned with the formation of urine and its elimination from the body are referred to as ***viscera of urinary tract*** or ***urinary organs***. They consist of the ***kidneys***, ***ureters***, ***urinary bladder*** and ***urethra*** (Fig. 20.1). In this chapter, we will consider the kidneys and the abdominal part of the ureters. The pelvic part of the ureters, urinary bladder and urethra will be considered in the Chapter on Viscera of Pelvis.

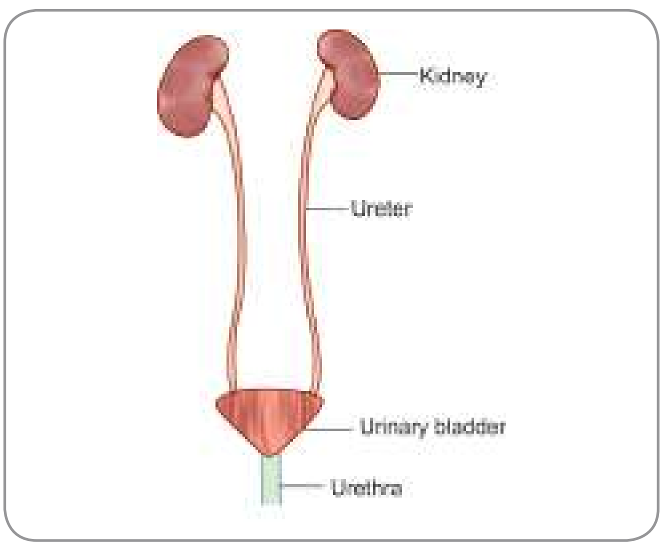


Fig. 20.1: The urinary organs

The ***suprarenal glands*** are endocrine organs. It is convenient to consider them here because of their close topographic relationship to the kidneys.

The kidneys and ureters together constitute the ***superior urinary organs***. The superior urinary organs and the suprarenal glands are primary retroperitoneal organs.

KIDNEYS

Other names: Rene, nephros.

The kidneys are a pair of excretory organs which are also involved in the endocrine functions of the body by secreting renin, erythropoietin and 1,25, dihydroxycholecalciferol. The kidneys lie against the posterior abdominal wall, are retroperitoneal and lie one on each side of the vertebral column at the level of T12 to L3 vertebrae. The right kidney is placed at a slightly lower level because of the presence of the liver in the right upper abdomen.

EXTERNAL FEATURES

Each kidney measures (during life) about 10 cm in length, 5–6 cm in breadth and 3 cm in thickness and has a characteristic bean-like shape (reniform) (Fig. 20.2). It has upper and lower ends, medial and lateral borders and anterior and posterior surfaces. The vertical axis is directed inferolaterally (Figs 20.2 and 20.3) so that its upper end is nearer to the median plane than the lower end and the horizontal axis is directed posteromedially. The ***upper end*** is about 2.5 cm (1 inch) from the median plane, while the ***lower end*** is about 7.5 cm (3 inches) from the latter. The ***anterior surface*** faces anterolaterally and the ***posterior surface*** faces posteromedially, as the kidney is closely related to the curvature of the body which forms the paravertebral gutter.

The ***lateral border*** is convex and the ***medial border*** is concave forming the ***hilum***. The terminal branches of the renal artery enter the kidney at the hilum and the renal

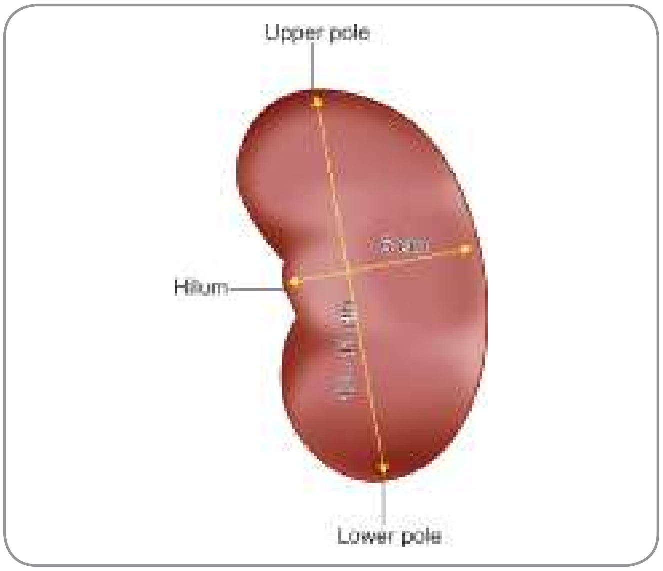


Fig. 20.2: Approximate dimensions of a kidney. The anteroposterior diameter is about 3 cm

veins emerge from it. The hilum also gives attachment to the upper expanded end of the ureter (called the ***renal pelvis***). The vein is the most anterior, the artery is in the middle and the renal pelvis is the most posterior. Examination of the hilum, therefore, enables one to distinguish between the anterior and posterior aspects of the kidney. The direction of the ureter (has to point downwards) enables the upper and lower ends of the kidney to be distinguished. In this way, it is possible to distinguish between isolated right and left kidneys.

On close examination of the renal hilum, it can be seen that the medial aspect of kidney immediately adjacent to the hilum has a space called the ***renal sinus***. The renal sinus is occupied by the renal pelvis and its calyces, vessels and nerves, and a variable amount of fat.

COVERINGS OF KIDNEY

Each kidney has four coverings from inside out. These coverings are:

1. Renal capsule or true capsule,
2. Perirenal fat or perinephric fat,
3. Renal fascia or fascia of Gerota, and
4. Paranephric fat or pararenal fat.

Renal Capsule

The kidney is intimately covered by a thin layer of collagen-rich fibrous tissue. This fibrous layer, which also has some elastic and smooth muscle fibres, envelopes the whole kidney and at the renal hilum, runs in to line the renal sinus. The fibrous layer, which is called the ***renal capsule*** or the ***true capsule*** of the kidney, can easily be stripped off in a healthy kidney. However, it might become adherent to the underlying tissue in some diseases.

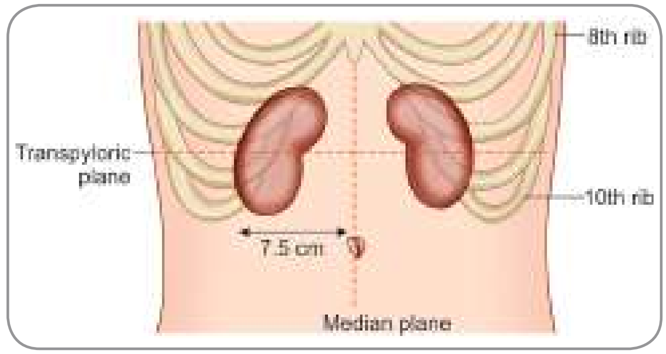


Fig. 20.3: Projection of the kidney to the front of the body

Perirenal Fat

Outside the capsule, the kidney is surrounded by a layer of ***perirenal fat*** (also called ***perinephric fat***). This fat is the thickest at the renal borders and also extends into the renal sinus. In chronic diseases, the loss of this fat leads to downward displacement of the kidney.

Renal Fascia

Outer to the perirenal fat, the kidney and the suprarenal are surrounded by a layer of dense fibromembranous tissue called the ***renal fascia.*** The renal fascia is considered to be the condensation of extraperitoneal tissue and is often referred to as ***Fascia of Gerota*** (Fig. 20.4). As it envelopes the kidney all around, it has an anterior and a posterior layer. Medially, the two layers proceed to ensheath the renal vessels and subsequently blend with the connective tissue sheaths of the latter.

Dissection

With prosected specimens, review your knowledge about the kidneys and ureters. Clean the ureter in the *in situ* specimen and compare with the prosected specimen. Turn and look at all the sides of the prosected specimen to study the hilum area more closely. In an isolated specimen of the kidney, make a coronal section by making an incision on the convex border. Study the internal structural organisation.

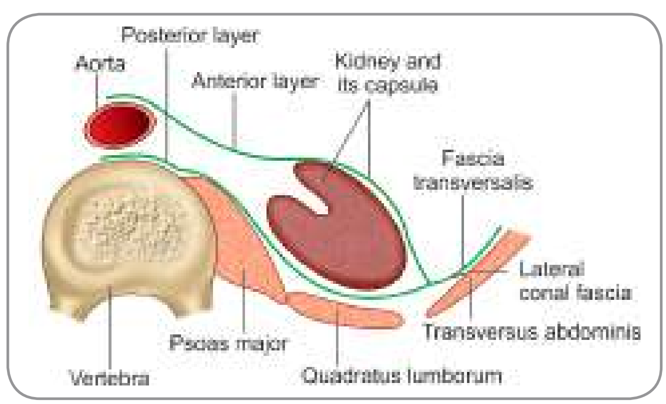


Fig. 20.4: Transverse section through kidney showing the arrangement of the renal fascia

Paranephric Fat

External to the renal fascia is a layer of pararenal fat, which actually is the extraperitoneal fat of the lumbar region. The pararenal fat is more on the posterior aspect and is seen as a dense mass between the renal fascia and the anterior layer of thoracolumbar fascia.

Added Information

- The renal hilum is something like an opening (aditus) to the renal sinus. Structures entering or exiting the kidney do so in the renal sinus and in the process of reaching or leaving the sinus, pass through the renal hilum.
- ***Fascia of Gerota:*** This is the renal fascia (also referred to as the perirenal fascia), named after the 19th–20th century Romanian surgeon Dimttrie Gerota. It consists of two layers–the anterior layer (or the ***anterior perirenal fascia*** or the ***Fascia of Toldt***) and the posterior layer (or the ***posterior perirenal fascia*** or the ***Fascia of Zuckerkendl***). Traced laterally, the two layers are continuous with each other (Fig. 20.4) forming the ***lateral conal fascia*** which merges with the parietal peritoneum and the fascia transversalis of the abdominal cavity. Traced medially, the anterior layer passes in front of the renal vessels, aorta and inferior vena cava and fuses with its fellow of the opposite side at the levels of L1 to L3 (sometimes till L5). The posterior layer passes over the quadratus lumborum and the psoas major to fuse with the psoas fascia in front of the lumbar vertebrae. Below the level of L3, the anterior and posterior layers merge with each other and also fuse with the perivascular connective tissue of the great vessels and the iliac vessels. Traced superiorly, the anterior and posterior layers enclose the suprarenal gland; above the gland, the layers were originally described to fuse with each other and with the fascia over the diaphragm (Fig. 20.5). However, according to newer concepts, the two layers do not fuse above the suprarenal gland. The posterior layer, on both sides, blends with the psoas fascia and the inferior phrenic fascia. The anterior layer, on the right side, fuses with the right inferior coronary ligament (thus forming the hepatorenal fascial fold) and on the left side, it fuses with the gastrosplenic ligament. Hence, the perirenal space is open to the bare area of liver on the right and the left extraperitoneal space on the left. Traced inferiorly, the two layers remain separate for some distance below the inferior pole of the kidney. They then merge to form a single multilamellar fascia that encloses the ureter. This common fascia is loosely adherent to the parietal peritoneum. (the older concept stated that the two layers do not fuse inferiorly; the posterior layer merges with the fascia over the iliacus muscle and the anterior layer becomes indistinct some distance below the kidney).
- ***Renal mobility:*** Normal renal mobility is about 3 cm. The kidneys are held in their normal 'fixed' positions by the perirenal tissues, vessels and ureters. The renal fascia sends collagen bundles into the pararenal fat, thus tethering the latter. The renal fascia, its attachments and collagen bundles, the perirenal and pararenal fat bodies, renal vessels and ureters hold the kidneys in position. Loss of perirenal and pararenal fat and distortion of the fasciae in conditions of disease cause renal displacement.

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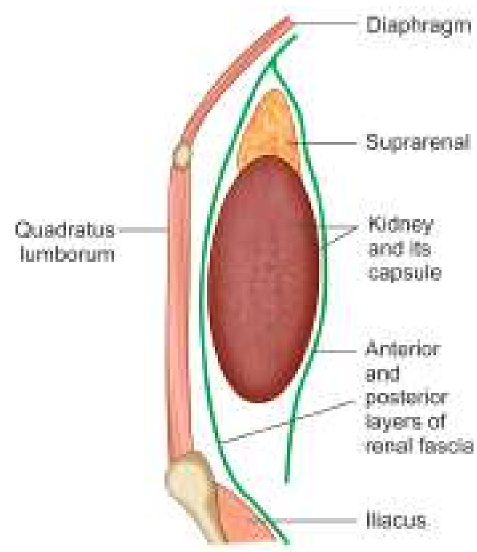


Fig. 20.5: Sagittal section through kidney to show arrangement of renal fascia (By the older concept).

Added Information *contd...*

- ***Endocrine functions of the kidneys:*** The kidneys secrete various factors which have metabolic functions. Of these secretions, some are more important than the others. Erythropoietin controls red blood cell formation. Renin influences blood pressure. 1,25-hydroxycholecalciferol is involved in calcium metabolism and modifies the action of parathormone.
- Karl Toldt, after whom the anterior layer of renal fascia is named, was a 19th century Austrian anatomist. Emil Zuckerkandl (pronounced Tsookerkandel), after whom the posterior layer is named, was also a 19th century Austrian anatomist.

RELATIONS OF KIDNEYS

Posterior Relations

As already noted, the kidneys lie on the posterior abdominal wall. Surgical approach to the kidney is easier from the posterior aspect than the anterior.

Each kidney rests on the following structures (Fig. 20.6):

- Diaphragm,
- Corresponding psoas major muscle,
- Corresponding quadratus lumborum muscle,
- Origin of the corresponding transversus abdominis muscle, and
- Medial and lateral lumbocostal arches (from which some fibres of the diaphragm take origin).

The diaphragm separates the upper part of the kidney from the pleura and from the twelfth rib. The left kidney being higher is also separated by the diaphragm from the eleventh rib. The subcostal nerves and vessels, and the ilioinguinal and iliohypogastric nerves course diagonally across the posterior surfaces of the kidneys.

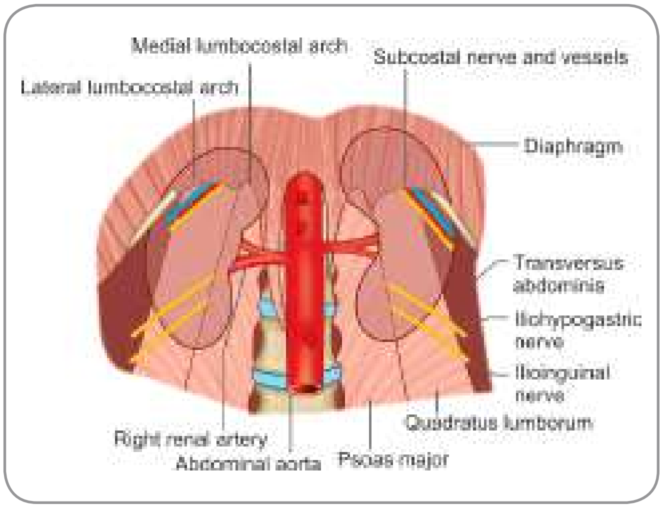


Fig. 20.6: Posterior relations of kidneys

Anterior Relations

The anterior relations vary on the right and the left sides.

Anterior Relations of the Right Kidney (Fig. 20.7)

- A small area on the superomedial part of the anterior surface is in contact with the right suprarenal gland;
- The medial part of anterior surface is overlapped by the duodenum;
- Below the suprarenal area, the anterior surface is in contact with the visceral surface of the liver (Fig. 20.7);
- The lower part is overlapped by the right colic flexure;
- Another small area on the inferomedial part of the anterior surface is in contact with few coils of jejunum.

Of these structures, the liver and the jejunum are separated from the kidney by peritoneum. The other structures are in direct contact with the kidney. Between this kidney and the liver lies the clinically significant ***hepatorenal pouch of Morison***.

Anterior Relations of the Left Kidney

- The upper medial part of the anterior surface is in contact with the left suprarenal gland;
- The upper lateral part of the anterior surface is in contact with the renal impression on the spleen;
- The pancreas runs across the middle of the anterior surface;
- The splenic artery runs across the kidney immediately above the pancreas (Fig. 20.7);
- Just above the area for the pancreas, the anterior surface of the left kidney comes in contact with the stomach and helps to form the stomach bed;
- The greater part of the anterior surface below the area for the pancreas is in contact with coils of jejunum;
- The left colic flexure comes in contact with the lower lateral part of the anterior surface.

The suprarenal, the pancreas and the colon are in direct contact with the kidney. However, the spleen, the stomach and the coils of jejunum are separated from it by peritoneum. The lienorenal ligament is attached to the front of the left kidney along the medial margin of the splenic area.

GROSS INTERNAL STRUCTURE

A coronal section through the kidney shows its internal structure (Fig. 20.8). The kidney is divisible into an outer cortex and an inner medulla. The medulla is composed of pale, conical areas of renal tissue called the ***renal pyramids***. The number of pyramids in a kidney is variable. The average number is about eight. The bases of the pyramids are directed towards the cortex (lying peripheral), whereas the apices converge towards the renal sinus. At the renal sinus, the apices project into calyces as papillae. The kidney tissue lying between the bases of the pyramids and the surface of the kidney (that is the subcapsular zone) is referred to as the ***cortex*** (called the cortical arches because this tissue

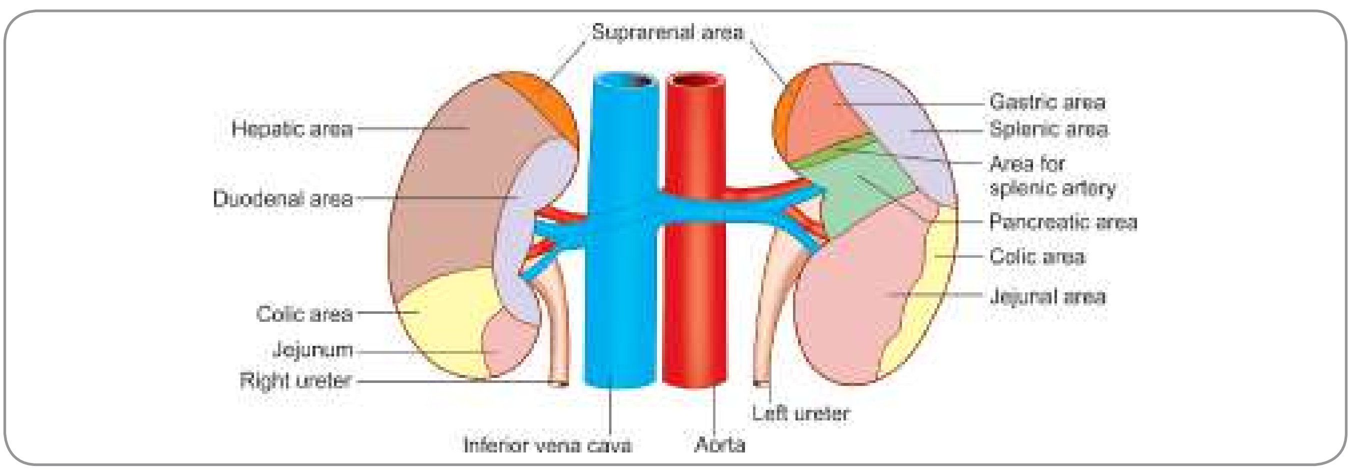


Fig. 20.7: Areas on anterior surfaces of right and left kidneys related to various viscera

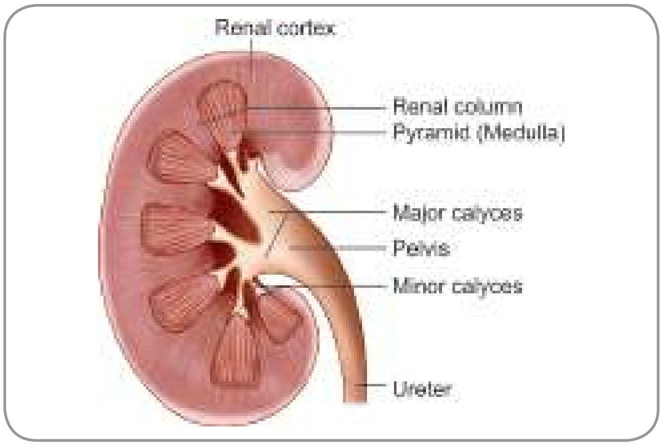


Fig. 20.8: Features to be seen in a coronal section through the kidney

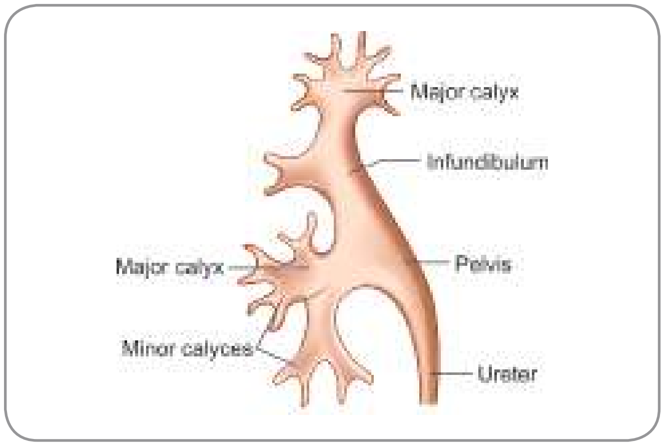


Fig. 20.10: Scheme to show the major and minor calyces

arches over the pyramidal bases). A renal pyramid and the cortex over it, together constitute a ***renal lobe*** which is visible without the aid of a microscope. Extensions of the cortex occupy the intervals between adjacent pyramids. These extensions are called ***renal columns***. Thin and lighter coloured radial extensions project from the bases of pyramids into the cortical arches. These are the medullary rays. The lighter radial medullary rays are separated by darker areas of the cortex. The cortex is histologically divisible into outer and inner zones. The inner zone is demarcated from the medulla by arcuate arteries and veins, which lie at the junction of the two. A thin layer of cortical tissue called the ***subcortex*** lies internal to the arcuate vessels. The cortex close to the medulla is called the ***juxtamedullary cortex*** and the cortex close to the capsule is ***outer or subcapsular cortex***.

Renal Hilum, Pelvis and Calyces

The central part of the medial border of the kidney is marked by the hilum. Examination of a transverse section across the kidney shows that the hilum leads into a space called the ***renal sinus*** (Fig. 20.9). The renal sinus is lined by the renal capsule and is predominantly occupied by the upper expanded part of the ureter called the ***renal pelvis and renal vessels***; the remaining area of the renal sinus is filled with fat. Within the renal sinus, the pelvis divides into two (or three) parts called ***major calyces*** (Greek.kalyx=cup of a flower; singular, calyx). Each major calyx divides into a number of minor calyces (Fig. 20.10). The end of each minor calyx is again shaped like a cup. The renal capsule that lines the renal sinus fuses with the adventitial connective tissue of the calyces. The papilla of a pyramid opens into a minor calyx. Sometimes, even two or three papillae open into a minor calyx. The major calyces, which are chambers of union of two or three minor calyces, drain into spaces called ***infundibula***. The renal pelvis is normally formed by the union of two infundibula, one from the upper and one from the lower pole calyces, but there can be one more infundibulum, which is formed from the mid-portion calyces.

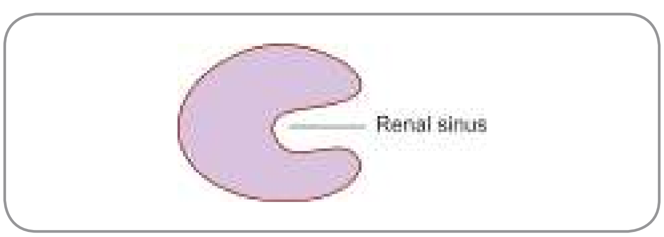


Fig. 20.9: Transverse section through a kidney to show the hilum

Dissection

Study the retroperitoneal area. Clean up the fascia and observe the disposition of the two kidneys. Clean the pararenal and perirenal fat taking care not to injure the renal pelvis and the calyces. Observe the suprarenal glands and their intimate relationship to the kidneys. Trace the renal vessels and the suprarenal vessels. Try to lift one of the kidneys from its resting bed on the posterior abdominal wall. Study the structures which lie posterior to the kidneys.

BLOOD SUPPLY OF KIDNEY

The kidneys are supplied by the renal arteries and are drained by the renal veins.

The renal arteries are lateral branches of abdominal aorta. They are given out at the level of the intervertebral disc between the L1 and L2 vertebrae. The right renal artery is longer and may be given out a little higher than the left; it crosses the right crus of the diaphragm and passes posterior to the inferior vena cava, right renal vein, head of pancreas and the second part of duodenum. The left renal artery, usually given out a little lower than the right, crosses the left crus of diaphragm and passes posterior to the left renal vein, body of pancreas and splenic vein.

As each renal artery passes to the corresponding renal hilum, it gives an inferior suprarenal branch, a branch to the ureter and multiple smaller branches which supply the perirenal tissues, renal capsule and the pelvis. Near the hilum of each kidney, the corresponding renal artery divides into anterior and posterior divisions. Within the renal sinus, these divide further into primary branches, each of which supplies a specific region of renal tissue, there being no anastomoses between arteries to the adjoining regions. These primary branches are called ***segmental arteries***. Based on their distribution, the kidney can be divided into five segments as shown in Figure 20.11. The anteromedial part of the upper pole forms the apical segment (both anterior and posterior surfaces) and the lower pole forms the inferior segment (both anterior and posterior surfaces). The central part is between the upper apical segment and the lower inferior segment; this is further subdivided into an anterior and a posterior portion. The upper part of the anterior portion forms the upper anterior segment (also called the ***superior segment*** and confined to the anterior surface only) and the lower part of the anterior portion forms the middle anterior segment (confined to the anterior surface only). The entire posterior portion of the central part forms the posterior segment (confined to the posterior surface and corresponds to the upper anterior and the middle anterior on the anterior surface).

The segmental arteries branch further into lobar, interlobar, arcuate and interlobular arteries and subsequently into afferent and efferent glomerular arterioles. The arterioles further form the intertubular capillary plexuses of the renal cortical circulation and the vasa recta of the renal medullary circulation.

The renal veins lie anterior to the renal arteries and drain into the inferior vena cava. The right renal vein is short (for obvious reasons) and is behind the head of pancreas and descending part of duodenum. The left renal vein is longer, runs behind the splenic vein and the body of pancreas and then crosses the anterior aspect of aorta before draining into the inferior vena cava. The left renal vein receives inferiorly the left gonadal vein and superiorly the left suprarenal vein.

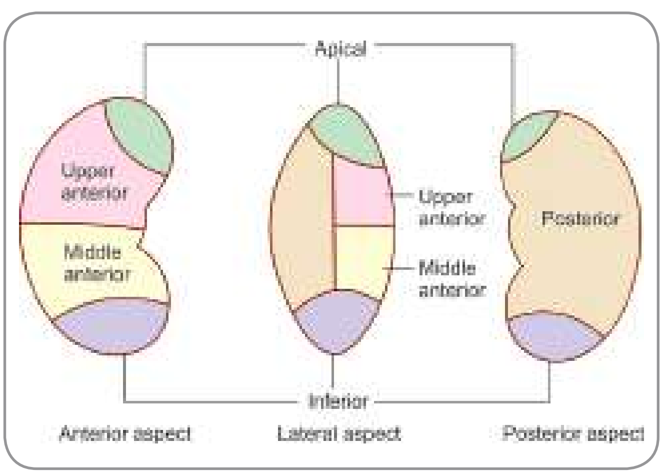


Fig. 20.11: Scheme to show the segments of the kidney

Added Information

- Vascular segments of the kidney (as described in five segments) are supplied by virtual end arteries. However, larger intrarenal veins have no segmental pattern and anastomose freely.
- Accessory renal arteries are common. They arise from the aorta either above or below the main renal artery and enter the kidney through the hilum. Developmentally, they are thought to be persistent lateral splanchnic arteries.
- Accessory arteries may sometimes arise from the coeliac or superior mesenteric arteries. Accessory vessels which go directly to the inferior pole necessarily cross the ureter and may obstruct it, resulting in conditions like hydronephrosis.
- ***Brodel's line:*** This is a relatively bloodless zone that runs longitudinally along the convex border of the kidney. Customarily described as the bloodless line of Brodel, this was considered as the most preferred site for surgical incisions of the kidney. However, several vessels do cross this zone and, therefore, this zone is not actually 'bloodless'.
- ***Internal arterial organization:*** The segmental arteries give out lobar branches; one lobar branch goes to one pyramid. Just before reaching the pyramid, the lobar artery divides into two or more interlobar arteries. These interlobar arteries ascend in the renal columns, but surrounding their corresponding pyamid. As they reach the junction of the cortex and the medulla (that is, the level of the pyramidal bases), each interlobar artery dichotomizes into two arcuate arteries. The arcuate arteries diverge from each other and at right angles to the parental interlobar artery; they arch between the cortex and the medulla (hence the name 'arcuate'). The arcuate arteries give out the interlobular arteries which run radially (thereby perpendicular to the parent arcuate artery) into the cortex. The terminal ends of adjacent arcuate arteries do not anastomose but turn into the cortex as additional interlobular arteries. Many of the interlobular arteries are tortuous as they proceed towards the cortex. Some of them are not and reach the surface of the kidney as perforating arteries; they anatomose with the capsular plexus of vessels found on the surface.
- ***Glomerular vascularity:*** The interlobular arteries give out lateral rami called the ***afferent glomerular arterioles***. These arterioles reach the Bowman's capsule to end in a glomerulus. The glomerulus, we know, is a tuft of capillaries; the capillaries are given out of the afferent arteriole reaching the particular glomerulus. The efferent glomerular arteriole arising from the glomerular capillary network soon divides into a peritubular capillary plexus that surrounds the proximal and distal convoluted tubules. Thus, there are two sets of capillaries: one proximal to the efferent arteriole and the other distal but both connected by the efferent arteriole. This is true for the efferent arterioles arising from all the glomeruli except those at the juxtamedullary junctional area.
- ***Venous organization:*** Small veins arise from the venous ends of the peritubular venous plexuses; such veins in the superficial areas of the renal cortex are called ***stellate veins***. These small veins converge and unite to form the interlobular veins,

contd...

Added Information *contd…*

which are found to accompany the interlobular arteries. The interlobular veins reach the corticomedullary junction and end in arcuate veins, which, in turn, drain into the interlobar veins. The interlobar veins anastomose freely and form the renal vein.

- ***Medullary vasculature:*** The lobar, interlobar, arcuate and interlobular arterial system constitutes the cortical vasculature or the renal cortical circulation. The medulla of the kidney derives its supply from the ***vasa recta***. The efferent glomerular arterioles of juxtamedullary glomeruli form long and wide vessels which descend into the medulla. As they descend, they may give small side branches to the adjacent peritubular capillary plexuses before reaching the medulla. On reaching the medulla, each of this descending vessel divides into 15 to 25 vasa recta. Each vas rectum runs straight into the depth of the medulla; it contributes small arterioles to a dense capillary network found surrounding the loops of Henle and the collecting ducts. After giving out the arterioles, the vas rectum turns up to start its journey as the ascending vas rectum. The venous ends of the aforementioned capillary network join this ascending vas rectum. The ascending vasa recta drain into the arcuate or interlobar veins. The ascending and descending vasa recta are in close proximity with each other and also with the loops of Henle. This anatomical proximity provides the structural basis for the counter-currrent exchange and multiplier phenomena.
- ***Clinical significance of left renal vein:*** The left renal vein is three times longer than the right. Because of this, the left kidney is the preferred organ in live donor nephrectomy. The left renal vein is also clinically significant because of its intimate relationship to the aorta. Sometimes, the vein may be double – the two members of the double encircling the aorta before joining the inferior vena cava. Such a condition is called the ***renal collar***. In surgeries for aortic aneurysm, it may be necessary to ligate the left renal vein; the left kidney does not suffer any harm if the ligature is placed to the right of the joining of the gonadal and suprarenal veins which provide channels of adequate collateral venous drainage.

LYMPHATIC DRAINAGE

The ***lymphatic drainage*** of the kidneys is into the lateral aortic lymph nodes. Three lymphatic plexuses are found: one around the renal tubules, one in the subcapsular area and the third in the perirenal fat. The latter two plexuses freely anastomose and all of them drain into the same nodes.

NERVE SUPPLY

The kidneys are supplied by autonomic nerves that reach them along the renal arteries. The sympathetic fibres are derived from the renal plexus (T10–L1). This accounts for the location of referred pain in cases of renal colic in the infraumbilical part of the anterior abdominal wall (even to the level of groin). The sympathetic innervation is primarily vasomotor in function. The parasympathetic nerve supply is through the vagus nerves; the exact role played by the parasympathetic innervation is not known.

SURFACE PROJECTION OF THE KIDNEYS

The position of the kidneys relative to the anterior abdominal wall is shown in Figure 20.3. Because of the presence of the liver on the right side, the right kidney lies slightly lower than the left kidney. The hilum of each kidney lies more or less in the transpyloric plane, a little medial to the tip of the ninth costal cartilage. In relation to the posterior surface of the body, the hilum of the kidney lies at the level of the first lumbar spine (Fig. 20.12).The upper pole lies at the level of the 11th thoracic spine. The lower pole lies at the level of the third lumbar spine. Keeping these facts in mind, and also keeping in mind the dimensions of the kidney (as shown in Figure 20.2), it is possible to draw the outline of the kidney relative to the surface of the body (Figs 20.3 and 20.12). While doing so, it has to be remembered that although the width of the kidney is actually about 6 cm, it appears to be only 4.5 cm when viewed from the front (or back) because of foreshortening (Fig. 20.13).

The area in which the kidney lies can be represented as a parallelogram (called Morris parallelogram though very often the name is referred to as ***Morrison's parallelogram***).

- The upper and lower boundaries of this parallelogram are formed by transverse lines drawn through the eleventh thoracic and third lumbar spines.
- The medial and lateral boundaries are formed by vertical lines drawn 2.5 cm and 9 cm from the median plane.

The width of the parallelogram is more than that of the kidney as the kidney lies obliquely within it.

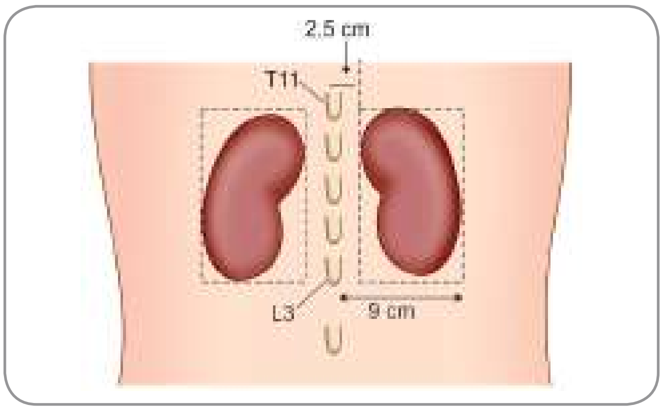


Fig. 20.12: Surface projection of the kidney on the back of the body

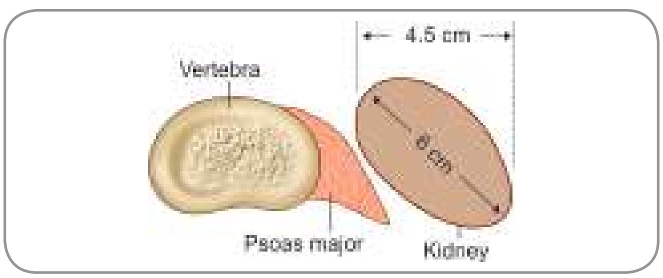


Fig. 20.13: Scheme to explain the foreshortening of the width of the kidney when viewed from the front or back

Histology

- The kidney contains several uriniferous tubules which are bounded by loose connective tissue. The uriniferous tubules are tortuous and densely packed; the connective tissue contains blood vessels, lymphatics and nerves.
- Each tubule has two distinct parts—the nephron and the collecting duct.
- Each nephron consists of a renal corpuscle which is involved in filtration of fluid from the plasma and the renal tubule which is concerned with selective absorption of material from the filtrate so as to form urine.
- Renal corpuscles are small rounded structures, about 0.2 mm in diameter and seen in the renal cortex. There are about one million renal corpuscles in a single kidney; their numbers reduce with age (especially after the fourth decade of life). Increased blood pressure accelerates the reduction.
- Bowman's capsule is the expanded end of a renal tubule. It is invaginated by a tuft of capillaries collectively called the ***glomerulus***. It has two walls—the ***parietal*** and the ***visceral***. The parietal wall is lined by simple squamous epithelium. The visceral wall has specialized epithelial cells called the ***podocytes***. The space between the two walls is called the ***urinary*** or the ***Bowman's space***.
- The podocytes, along with the glomerular endothelium, is concerned with filtration from the plasma.
- The renal or the uriniferous tubule starts in the glomerular capsule. It consists of, successively, the proximal convoluted tubule, descending thick limb of loop of Henle, ascending loop of Henle and the distal convoluted tubule.
- The distal convoluted tubule finally leads to the collecting duct.
- The proximal convoluted tubule is lined by cuboidal epithelium with brush border, the thin segment of loop of Henle by low cuboidal or squamous cells, the thick segment by cuboidal epithelium richly studded with mitochondria and the distal tubule by cuboidal epithelium but with few microvilli.

Clinical Correlation

Congenital Anomalies of the Kidney

- Anomalies according to number:
  - Agenesis of one or both kidneys.
  - There may be duplication of a kidney.
- Anomalies of shape:
  - The lower poles of the two kidneys may be fused (***horseshoe kidney***).
  - The two kidneys may form one mass lying in the midline (***pancake kidney***).
  - The foetal kidney is lobulated. Foetal lobulation may persist.
- Anomalies of position:
  - The kidneys may lie in the sacral region, or in the lower lumbar region because of the failure of normal ascent.
  - Both the kidneys may lie on one side of the midline.
- In the foetal kidney, the hilum faces anteriorly and later rotates to a medial position. The hilum may remain ***unrotated***, or may rotate in a reverse direction.

contd...

Clinical Correlation *contd...*

- The kidney may be full of cysts (***congenital polycystic kidney***).
- Additional renal arteries, arising from the aorta below (more common) or above the level of the normal renal artery, may be present (***aberrant renal arteries***). Such an artery can press on the ureter leading to obstruction.
- Underdevelopment (hypoplasia) or overdevelopment (hyperplasia) may occur. Adrenal tissue may be present within the kidney substance.

Renal Angle

The renal angle is the angle between the lower border of 12th rib and the lateral border of erector spinae muscle. At this angle the kidney lies closer to the posterior abdominal wall as the costodiaphragmatic recess is not present below the 12th rib. The posterior incision for approaching kidney starts from the renal angle only and extends downward and forward. Renal pain is usually felt here. Any perinephric abscess may be felt as a swelling at renal angle. The loin to groin pain, typical of calculi, starts at the renal angle.

Injuries

- The kidney may be injured by a fall or a blow on the loin.
- It can also be hurt due to crushing injuries.

Renal Calculi

A stone lodged in the kidney may be painless. Sometimes it gives a dull pain that may be felt posteriorly in the renal angle, or anteriorly in the hypochondrium (***fixed renal pain***). Urinary obstruction caused by calculi or other causes can lead to dilatation of the ureter above the site of obstruction (***hydroureter***). It can also lead to dilatation of the renal pelvis and calyces (***hydronephrosis***).

Operations for removal of renal calculi may involve opening of the renal pelvis (***pyelolithotomy***), or an incision into the kidney (***nephrolithotomy***). Stones can be seen and can be removed as a whole or after breaking them into small pieces. In ***lithotripsy***, an instrument (***lithotriptor***) generates powerful shock waves that can pass through tissues of the body and can be focused at a given site. Such waves can reduce a stone to sand, or to very small pieces, which can then be flushed out through the urinary passages. A stone passing down the ureter can get arrested somewhere along its length. This is more likely to occur at places where the ureter is normally constricted.

Infections

Infection of the kidney and pelvis is called ***pyelonephritis***. It may be acute or chronic. Sometimes the kidney can be reduced to a bag of pus, most of the kidney tissue being destroyed (***pyonephrosis***). Infection from a kidney can spread to tissues around it, leading to a ***perinephric abscess***.

URETERS

The ureter (right or left) is a thick muscular tube that conveys urine from the corresponding kidney to the urinary bladder. It extends from the pelvi-ureteric region to the urinary bladder. It is about 25 cm (10 inches) long. Its average diameter is about 3 mm. The upper half of this length lies on the posterior abdominal wall and the lower half in the true pelvis. The abdominal part of each ureter runs downward (with a slight medial inclination). Anteriorly, it is covered by the peritoneum of the posterior abdominal wall. Posteriorly, it rests on the psoas major. At the brim of the pelvis, the ureter crosses the upper end of the external iliac artery (and vein), and comes to lie on the lateral wall of the pelvis. Here, it runs backward and laterally. Finally, it leaves the pelvic wall and turns medially and forward to reach the posterolateral part of the urinary bladder. The ureter, normally has constrictions in three places—(1) at its junction with the renal pelvis–pelviureteric junction; (2) where it crosses the pelvic brim; (3) at its passage through the wall of urinary bladder.

RELATIONS OF ABDOMINAL PARTS OF URETERS

The relations of the abdominal parts of the ureters are different on the right and left sides.

Anterior Relations of Right Ureter (from above Downwards)

- Descending and horizontal parts of the duodenum;
- Right gonadal vessels;
- Right colic and ileocolic branches of the superior mesenteric artery;
- Root of the mesentery;
- Coils of ileum.

Anterior Relations of Left Ureter (from above Downwards)

- Left gonadal vessels;
- Left colic vessels;
- Sigmoid colon and sigmoid mesocolon.

Posterior Relations (Common to both Ureters)

- Psoas major and its covering fascia;
- Genitofemoral nerve passing downward and laterally;
- Tips of transverse processes of all lumbar vertebrae, separated by psoas major.

Clinical Correlation

Congenital Anomalies of the Ureters

- The ureter may be partially, or completely, duplicated. The duplication (duplex ureter) may accompany duplication of the kidney or may be independent.

contd...

Clinical Correlation *contd...*

- The ureter may open at an abnormal site (ectopic ureters):
  - Into the vagina;
  - Into the rectum;
  - Into the urethra;
  - Into the ductus deferens;
  - Into the seminal vesicle.
- There may be obstruction to the ureter. Obstruction may be a result of stenosis, or presence of valves.
  - The upper end may be blind.
  - The part of the ureter above the obstruction dilates (***hydroureter***).
  - Obstruction can also lead to dilation of the renal pelvis and kidney (***hydronephrosis***).
- Sometimes the right ureter may lie behind the vena cava (the real defect being in the position of the vena cava).

Ureteric colic: It usually occurs due to obstruction of the ureteric lumen by a calculus. The calculus can lodge at one of the ureteric constrictions—at the pelvi ureteric junction, at the pelvic brim or at the ureterovesical junction. The pain typically begins at the loin and radiates to the groin.

Injuries

The ureters may be injured in operations on the abdomen which may result in strictures. The usual sites of injury are:

- Where it is crosses the iliac vessels,
- In the ovarian fossa,
- Where it is crossed by the uterine artery (near the lateral margin of cervix) or,
- At base of the bladder.

Radiographic visualisation of the renal pelvis and ureter: The renal pelvis and the ureter are frequently visualised in the living by taking skiagrams after injecting radio-opaque dye into a vein. The dye is excreted by the kidney into the urine rendering the pelvis, ureter and urinary bladder visible. The procedure is called ***excretion urography*** (also called ***intravenous*** or ***descending pyelography*** or ***urography***). The ureters can also be visualised by direct injection of radio-opaque dyes into them by using an instrument introduced through the urethra and urinary bladder. This procedure is called ***ascending or retrograde pyelography*** (or urography).

In interpreting such urograms, it is important to know the skeletal relationships of the ureters.

- The abdominal part runs downward in line with the tips of the transverse processes of lumbar vertebrae;
- After entering the pelvis, the ureter runs across the sacroiliac joint, and the anterior border of the greater sciatic notch to reach the ischial spine;
- The ureter turns medially at this spine. Its point of termination corresponds to the pubic tubercle.

Development

The urinary system develops from the nephrogenic cord which develops as a part of the intermediate mesoderm. Two provisional embryonic excretory organs, namely the ***pronephros*** and the ***mesonephros*** appear in succession

contd...

Development ***contd...***

and are later replaced by permanent kidney tissue of metanephros. This is recapitulation of phylogeny in ontogeny. In an early embryo, the pronephros appears as a solid cord in the gap between the coelom and the somites. Some tubules arise from the pronephros and join to form the pronephric duct. The pronephric duct opens into the cloaca. The pronephros starts disappearing soon. The mesonephros then arises but before the complete disintegration of the pronephros. The mesonephros undergoes cranio-caudal modifications. Glomeruli are formed and a set of mesonephric tubules arise. The mesonephros, however, does not function in the human. Caudal to the mesonephros, the nephrogenic cord gives rise to the metanephric blastema. Meanwhile, a hollow outgrowth called the ***ureteric bud*** arises from the mesonephric duct, close to its junction with the cloaca. The cranial end of the ureteric bud enlarges and comes in contact with the metanephric blastema. The enlarged portion soon divides into two, forming the rudimentary major calyces. Further subdivision causes the appearance of the minor calyces. More division leads to the formation of the collecting ducts. The cap of metanephric blastema over the calyces and collecting ducts forms the excretory part of the kidney, namely the convoluted tubules and the glomeruli.

The cranial growth of the blastema and the dimunition of body curvature leads to what is called the ***ascent of kidney***. The kidneys move up from a pelvic position to the lumbar position. The ureters develop from the lower undilated parts of the ureteric buds.

Failure of ascent of kidney can result in congenital pelvic kidney. Fusion of the two lower poles can hamper ascent; such a fusion also results in horse-shoe kidney. Persistence of the blood supply of the lower levels can give rise to aberrant arteries. Separation of the ureteric buds into two parts results in duplication of ureters.

SUPRARENAL GLANDS

Other names: Adrenal gland, glandula atrabiliaris, epinephros.

As implied by the name, the right and left suprarenal glands lie in close relationship to the upper poles of the corresponding kidneys. They are paired endocrine glands, richly vascular and yellowish pink in colour. They are enclosed with the kidney in the renal fascia, but lie outside the renal capsule (Fig. 20.5). Each gland is about 50 mm in vertical diameter, about 30 mm from side to side and about 10 mm from front to back.

RIGHT SUPRARENAL GLAND

The right suprarenal gland is irregularly tetrahedral in shape, has three borders (anterior, medial and lateral), three surfaces (anteromedial, anterolateral and posterior), an apex and a base.

- The anterior border near the apex bears the hilum through which the right suprarenal vein drains into the inferior vena cava.
- The medial border lies lateral to the right coeliac ganglion and the right inferior phrenic artery.
- The anteromedial surface is related to the inferior vena cava.
- The anterolateral surface is related to the right lobe of the liver (the upper part of the surface is related to the bare area of the liver and the lower part to the visceral surface of the liver).
- The upper part of the posterior surface is related to the diaphragm and the lower part to the upper pole of the right kidney.

LEFT SUPRARENAL GLAND

The left suprarenal gland is semilunar in shape, has two borders (lateral and medial), two surfaces (anterior and posterior) and two ends/poles (upper and lower).

- The lateral border is concave and overlaps the left kidney.
- The medial border is convex and is related to the inferior phrenic artery, left gastric artery and left coeliac ganglion.
- The upper part of the anterior surface is related to the posterior surface of the cardiac end of the stomach and the lower part is related to the body of pancreas and the splenic artery. The anterior surface bears the hilum near the lower end.
- The lateral part of the posterior surface is related to the anterior surface of the left kidney and the medial part of the posterior surface is related to the left crus of diaphragm.

STRUCTURE AND FUNCTIONS OF THE SUPRARENAL GLANDS

The suprarenal gland is surrounded by a capsule. Septa arising from the capsule extend into the substance of the gland. The gland is made up of a superficial part called the ***cortex*** and a deeper part called the ***medulla***. The volume of the medulla is about one-tenth of the cortex. Both the medulla and the cortex consist of cords or groups of cells separated by sinusoids. On the basis of the arrangement of its cells, the cortex can be divided into three zones:

1. The outermost zone is called the ***zona glomerulosa***—the cells are arranged in the form of inverted U-shaped structures or acinus-like groups in this zone.
2. The next zone is called the ***zona fasciculata***—the cells are arranged in straight columns here.
3. The innermost zone is called the ***zona reticularis***—this zone has cords of cells which branch and

anastomose with each other, thus forming a kind of reticulum.

The medulla is made up of groups of cells, some of which may be arranged in columns. The cell groups or columns are separated by wide sinusoids. Nerve fibres and neurons are also present.

HORMONES OF SUPRARENAL GLANDS

The suprarenal being an endocrine gland, different parts of it produce different hormones.

Hormones of Suprarenal Cortex

- The cells of the zona glomerulosa produce the hormone ***aldosterone*** that helps to maintain the water and electrolyte balance of tissues.
- The cells of the zona fasciculata produce ***hydrocortisone*** (and related compounds). These have widespread effects all over the body, including the maintenance of carbohydrate balance.
- The cells of the zona reticularis produce ***sex hormones*** including progesterone, oestrogens and androgens.

Hormones of Suprarenal Medulla

The chromaffin cells or the phaeochromocytes of the suprarenal medulla are modified postganglionic sympathetic neurons. They receive the terminals of preganglionic sympathetic neurons and secrete noradrenalin and adrenalin into the blood mainly at times of stress (fear, anger, etc.) and result in widespread effects similar to those of stimulation of the sympathetic nervous system (e.g. increase in heart rate and blood pressure).

Added Information

Both functionally and embryologically, the medulla of the suprarenal gland is distinct from the cortex. When the suprarenal gland is fixed in a solution containing a salt of chromium (e.g. potassium dichromate), the cells of the medulla show yellow granules in their cytoplasm. This is called the ***chromaffin reaction*** and the cells that give a positive reaction are called ***chromaffin cells***. The cells of the cortex do not give this reaction. A similar reaction is also given by cells of sympathetic ganglia.

BLOOD VESSELS, LYMPHATICS AND NERVES OF THE SUPRARENAL GLANDS

Each suprarenal gland receives three suprarenal arteries:

1. ***Superior*** from the corresponding inferior phrenic artery;
2. ***Middle*** from the abdominal aorta, and
3. ***Inferior*** from the corresponding renal artery.

The suprarenal gland is drained by ***only one vein***. On the right side, this vein drains directly into the inferior vena cava and, on the left side, into the left renal vein.

The lymphatics of the gland drain into the lateral aortic nodes.

The medulla of the suprarenal gland receives numerous preganglionic sympathetic nerves from the T8 to L1 levels.

Development

The suprarenal glands develop from two primordia, namely the ***ectodermal*** and ***mesodermal primordia***. The ectodermal primordium gives rise to the medulla and the mesodermal primordium gives rise to the cortex.

Mesothelial cells present on the posterior abdominal wall of the embryo start proliferating to form a mass of cells called the ***foetal*** or ***primitive cortex***. More mesothelial proliferation is added to this primitive cortex on its outer aspect. The latter cells are smaller and collectively form the definitive cortex. Sympathetic cells appear near the primitive cortex by around the 4th week of development. They form a mass on the medial aspect of the cortex initially. Later, they are encapsulated by the definitive cortex. Chromaffin reaction of the medullary cells occur by around the 22nd week of development. Secretion of adrenalin is noted even by the 8th week.

The suprarenal gland is very large in a foetus. The foetal cortex, which is large in the foetus, involutes after birth, leading to reduction in the size of the gland.

Clinical Correlation

- Suprarenal cortical tissue may be present at various ectopic sites including the kidney substance, the ovaries and the broad ligament.
- The entire suprarenal may be ectopic and may be fused to the kidney or to the liver.
- Congenital hyperplasia (overdevelopment) of the cortex in the males leads to the ***adrenogenital syndrome*** marked by very early development of secondary sexual characters. In a female, it may cause enlargement of the clitoris and the child may be mistaken for a male (***pseudohermaphroditism***).
- ***Cushing's syndrome:*** Adrenal hyperplasia with excessive secretion of glucocorticoids leads to Cushing's syndrome manifested by truncal obesity, hypertension and hirsutism in females.
- Chronic deficiency of cortical hormones leads to ***Addison's disease***, characterised by increased skin pigmentation, muscular weakness, weight loss and hypotension.
- Phaeochromocytoma, a tumour of medulla produces paroxysmal hypertension due to secretion of large amounts of catecholamines.

Multiple Choice Questions

1. The renal pelvis is actually the:
   a. Expanded end of ureter
   b. The continuation of renal sinus
   c. Place of filtrate
   d. Place of reabsorption
2. The subcortex of the kidney:
   a. Lies internal to arcuate vessels
   b. Between two arcuate vessels
   c. Is the outer portion of medulla
   d. Is always subcapsular
3. What is false about the renal angle:
   a. It is the angle between the inferior border of 12th rib and lateral border of erector spinae
   b. Renal pain is felt in the angle
   c. Pain of ureteric colic reaches here the last
   d. Perinephric abcess presents as a swelling here
4. Each suprarenal gland is drained by:
   a. A pair of veins
   b. A single vein
   c. Variable number of veins
   d. Two on the left and one on the right
5. Fat occupying the renal sinus is the:
   a. Perirenal fat
   b. Pararenal fat
   c. Both peri and pararenal fat
   d. Endonephric fat

ANSWERS

1. a **2.** a **3.** c **4.** b **5.** a

Clinical Problem-solving

Case Study 1: During investigations, a pyelographic procedure is performed on a 47-year-old man.
- What do you understand by the term and what/ which viscera are being tested for?
- What are the types of pyelography you are aware of?
- If you read hydroureter and hydronephrosis in the contrast radiograph given to you, what exactly has happened?

Case Study 2: A 56-year-old man suffers from ureteric colic.
- Which feature can be taken to differentiate the pain of ureteric colic from other painful conditions?
- How does the anatomy of ureter predispose to ureteric calculi or consequences of a calculus.

(For solutions see Appendix).

Chapter 21

Posterior Abdominal Wall and Related Structures

Frequently Asked Questions

- Write notes on: (a) Thoracolumbar fascia, (b) Lateral branches of abdominal aorta, (c) Abdominopelvic splanchnic nerves.
- Write briefly on: (a) Quadratus lumborum, (b) Inferior vena cava and its tributaries.

The posterior abdominal wall is a separate region of significance by virtue of several important structures lying on and related to it. Important muscles, fasciae, nerves, vessels and lymphatics are present in this region. It can grossly be defined as the region of the abdominal wall between the two mid-dorsal lines, below the posterior attachments of diaphragm and above the pelvis. It is continuous anterolaterally with the anterior abdominal wall, superiorly with the posterior thoracic wall and inferiorly with the pelvis.

BONES OF POSTERIOR ABDOMINAL WALL

The posterior abdominal wall has a skeletal framework that not only gives support to the region concerned but also plays a crucial role in weight-bearing and posture maintenance of the individual. The members of this skeletal framework are:

- Lumbar vertebrae—five in number;
- Sacrum and coccyx; and
- Hip bones which participate in the formation of the bony pelvis.

The bodies, intervertebral discs and the transverse processes of the five lumbar vertebrae form the median part of the posterior wall. The lateral part of the wall extends from the 12th rib above to the pelvic brim below. The bodies and the intervertebral discs increase in height and width from the 1st to the 5th rib. The 12th rib curves downward and laterally to the level of the 2nd lumbar disc. The iliac crest curves upward and laterally to the level of the lower part of the L4 vertebra.

Clinical Correlation

- ***Congenital malformations of lumbar vertebrae:***
  - ***Spina bifida:*** Vertebrae have a complex developmental history and abnormalities resulting from maldevelopment are frequently seen. The vertebrae develop after the spinal cord. For this, proper closure of the neural tubes is necessary. Failure of fusion of the posterior neuropore either completely or partially results in various types of spina bifida, where the two halves of the neural arch may fail to fuse in the midline. The types of spina bifida depending on the level of severity of non-closure of posterior neuropore are:
    - ***Spina bifida occulta:*** The gap between the neural arches is small and there is no obvious deformity apparent on the surface (the defect is hidden from external view and so it is called occulta; occult=hidden);
    - ***Meningocoele:*** The gap is large, wherefrom the meninges and nerves or either of the two bulge out and form a visible swelling; when such a swelling contains only meninges and cerebrospinal fluid (CSF), it is called a ***meningocoele*** and when neural elements are also present in the swelling, it is called a ***meningomyelocoele***.
  - Two or more vertebrae which are normally separate may be fused to one another. The 5th lumbar vertebra may be partially or completely fused to the sacrum (***sacralisation of 5th lumbar vertebra***). Alternately, the 1st piece of the sacrum may form a separate vertebra (***lumbarisation of 1st sacral vertebra***).
  - Abnormality in ossification of a vertebra may result in a condition in which the spine, laminae and inferior articular processes are not fused to the rest of the vertebra.
- ***Spondylolisthesis:*** Normally, vertebral bodies do not slip forward over one another because of the restraining influence of the inferior articular processes. However, when there are defects of formation, body weight can cause the body of the 5th lumbar vertebra to slip forward over the sacrum. This condition is called ***spondylolisthesis***. Sometimes, a similar condition may affect the 4th lumbar vertebra that may then slip forwards over the 5th lumbar vertebra. Spondylolisthesis can be a cause of persistent low back pain.

contd...

Clinical Correlation *contd...*

- ***Fractures of lumbar vertebrae:*** The lumbar vertebrae may be fractured by direct injury. Such injury usually results in fracture of the spinous process, transverse process or lamina. If the lumbar spine is forcibly flexed (as in a fall from a height), the body of a vertebra can be compressed. In a compression injury, the vertebral arch and the ligaments around the body can remain intact and can prevent the spinal cord from being injured. In more severe injuries, compression of the body of a lumbar vertebra may be combined with fracture of the articular processes (***fracture dislocation***). The vertebrae involved become unstable and injury to structures within the spinal canal can result. Such injury in the lumbar region leads to the ***cauda equina syndrome***, where flaccid paraplegia, loss of sensations over the perineum and upper medial area of thighs (the area corresponding to that which comes in contact with a saddle) and incontinence of urine and of faeces are seen.
- ***Lumbar puncture:*** The term ***lumbar puncture*** is applied to a procedure in which a long needle is passed into the subarachnoid space through the interval between the 3rd and 4th lumbar vertebrae, or sometimes through the interval between the 4th and 5th lumbar vertebrae. The lower end of the spinal cord lies at the level of the lower border of the 1st lumbar vertebra and the subarachnoid space (containing the cerebrospinal fluid) extends down to the level of the lower border of the 2nd sacral vertebra. Hence, a needle passed into the lower lumbar part of the vertebral canal does not injure the spinal cord. By doing the procedure of lumbar puncture, samples of cerebrospinal fluid (CSF) can be obtained for examination. The colour, cellular content, chemical composition (especially the protein and sugar content) and the pressure of CSF can be estimated. Air or radio-opaque dyes can be introduced into the subarachnoid space for certain investigative procedures. A skiagram taken after injecting iodinized oil into the subarachnoid space outlines the space. Anaesthetic agents injected into the subarachnoid space act on the lower spinal nerve roots and render the lower part of the body insensitive to pain. This procedure, called ***spinal anaesthesia***, is frequently used for operations on the lower abdomen and on the lower extremities.
- ***Prolapse of an intervertebral disc:*** The intervertebral discs are very strong in the young. With advancing age, however, the annulus fibrosus becomes weak and it then becomes possible for the nucleus pulposus to burst through it. This is called ***prolapse of the intervertebral disc*** (though it is really prolapse of the nucleus pulposus). A prolapsed nucleus pulposus usually passes backward and laterally and may press upon the nerve roots attached to the spinal cord at that level resulting in local pain in the back. When nerves are compressed upon, there is shooting pain along the course of the nerve involved. Disc prolapse occurs most frequently in the lumbosacral region and results in pain shooting down the back of the leg and thigh along the course of the sciatic nerve. This condition is called ***sciatica***.

FASCIAE OF POSTERIOR ABDOMINAL WALL

The soft tissues of the posterior abdominal wall consist of several layers of fasciae. These fasciae divide the soft tissues of this region into anatomically distinct compartments. These fasciae are the thoracolumbar fascia, psoas fascia, iliac fascia, perirenal fascia and lateral conal fascia. The extraperitoneal connective tissue in this region also deserves a special mention. All the fasciae of this region are collectively called the ***endoabdominal fascia***.

Thoracolumbar Fascia

Other names: Thoracolumbar aponeurosis, lumbodorsal fascia.

The thoracolumbar fascia is intimately related to the muscles of the posterior abdominal wall. It has three layers, namely anterior, middle and posterior (Fig. 21.1).

The ***anterior layer*** (also called the ***quadratus lumborum fascia***) covers the anterior surface of the quadratus lumborum. It is attached medially to the anterior surfaces of the transverse processes of the lumbar vertebrae and merges laterally with the posterior layer. The anterior layer is also attached below to the iliac crest. Its upper end forms the lateral arcuate ligament that gives origin to the fibres of diaphragm.

The ***middle layer*** separates the erector spinae from the quadratus lumborum. It is attached medially to the tips of the transverse processes of the lumbar vertebrae and, laterally, it blends with the posterior layer. The middle layer is attached to the 12th rib above, and to the iliac crest below.

The ***posterior layer*** covers the deep muscles of the back. It is attached medially to the lumbar and sacral spines. Laterally, it blends with the middle and anterior layers.

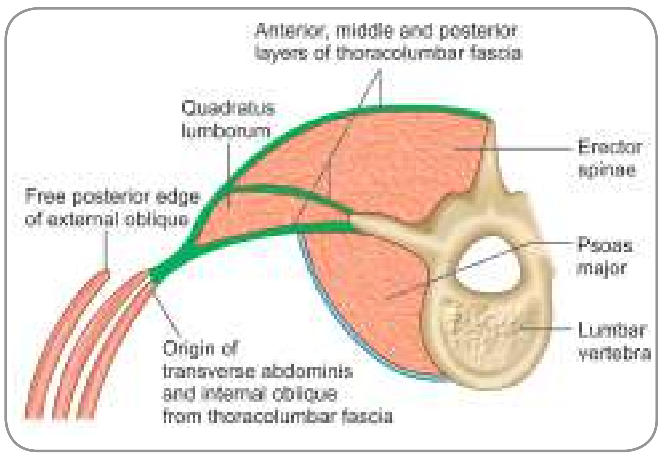


Fig. 21.1: The lumbodorsal fascia

All the three layers merge to form an aponeurosis that gives attachment to the internal oblique transversus abdominis muscles. The posterior layer can be traced upward (superficial to the erector spinae) into the thorax at the upper end of which it becomes continuous with the deep cervical fascia. The serratus posterior inferior and superior are superficial to it. Inferiorly, the posterior layer can be traced medially to the sacrum and laterally to the iliac crest.

Psoas Fascia

Other name: Psoas sheath.

This is the fascia that covers the anterior aspect of the psoas major muscle. Medially, it is continuous with the attachments of the muscle to the transverse processes and bodies of the lumbar vertebrae. Laterally, in the upper part, it blends with the anterior layer of the thoracolumbar fascia and in the lower part, it is continuous with the iliac fascia. The psoas fascia separates the mass of psoas major muscle from the retroperitoneal structures lying anterior to the muscle.

Iliac Fascia

This is the fascia covering the anterior aspect of the iliacus muscle. It blends with and is inseparable from the psoas fascia. In the upper part, it merges with the psoas fascia and the anterior layer of the thoracolumbar fascia over the quadratus lumborum. In the lower part, as the muscle leaves the region of the hip bone and enters the thigh, the fascia merges with the periosteum of the ileum at the pelvic brim.

Renal and Lateral Conal Fasciae

The posterior layer of the renal fascia (fascia of Gerota) is adherent to the psoas, iliac and thoracolumbar fasciae. The anterior layer separates the kidney and the perirenal space from the still anterior viscera—these viscera being the duodenum and the ascending colon on the right and the duodenum and the descending colon on the left. In the lower part of the region, the two layers enclose the ureter. However, when traced near the pelvic brim, these two layers thin out and are lost in the general loose connective tissue of the retroperitoneum. The lateral conal fascia is formed by the union of the anterior and posterior layers laterally and can be seen to fuse with the fascia over the transversus abdominis muscle. It thins out and is also lost in the inferior aspect.

Interfascial and Extraperitoneal Connective Tissue

Loose sheaths of connective tissue are seen between and around the various fascial layers. Adipose tissue may be present in these sheaths and markedly increased in the obese. The retroperitoneal vessels lie in this connective tissue. The nerves of the lumbar plexus lie deep, beneath the psoas and iliac fasciae.

Clinical Correlation

The psoas and iliac fasciae are imperceptibly merged and are usually referred to as the common iliopsoas fascia. This common fascia extends to the thigh (along the muscles to their insertions). Inflammatory secretions from the vertebrae, paraspinal tissues and retroperitoneal areas may collect underneath the fascia within the muscle mass. Such secretions are usually kept confined within the muscle by the fascia; these secretions may then track down to the thigh and appear in the thigh region where the fascia is the thinnest.

MUSCLES OF POSTERIOR ABDOMINAL WALL

The muscles of the posterior abdominal wall are (Table 21.1):

- Psoas major,
- Psoas minor,
- Iliacus, and
- Quadratus lumborum.

Additional Notes on the Muscles of the Posterior Abdominal Wall

Psoas major: The psoas major or the greater psoas muscle (Greek.psoas=muscle of the loin) has important relations. Just below its upper end, this muscle is crossed by the medial arcuate ligament. This ligament gives origin to some fibres of the diaphragm, which, therefore, overlap the uppermost part of the psoas major. The part of the muscle that arises from the intervertebral disc between T12 and L1 (there may also be a slip arising from the side of T12 vertebral body) actually lies in the thorax (posterior mediastinum) and may be related to the pleura.

The lumbar plexus of nerves lies embedded in the posterior part of this muscle mass. The ventral rami of the upper four lumbar spinal nerves, as they emerge from the respective intervertebral foramina, plunge into the muscle substance.

From the level of the diaphragm to the level of its insertion, the psoas major can be described to have three parts. The upper part forms part of the posterior abdominal wall and is called the ***abdominal part***. The intermediate part crosses the sacroiliac joint and runs along the brim of the true pelvis; it is, therefore, called the ***pelvic part***. The lower part of the muscle passes behind the inguinal ligament to enter the thigh and is called the ***femoral part***.

The ***abdominal part*** of the muscle is related anteriorly (on both sides) to the kidney, renal vessels, ureter, gonadal vessels and genitofemoral nerve. The medial margin of

Table 21.1: Muscles of the posterior abdominal wall

Muscle	Psoas major	Psoas minor	Iliacus
Origin	Through several slips from the following: • Transverse process of each lumbar vertebra (anterior surface) • Intervertebral discs and bodies of vertebrae (lateral parts). Of the five slips, the highest is between T12 and L1 and the lowest is between L4 and L5 (Fig. 21.2) • Tendinous arches along the sides of upper four lumbar vertebrae	• Intervertebral disc between T12 and L1 • Adjoining parts of bodies of vertebrae	• Iliac fossa (on inner side of hip bone) • Iliac crest, inner lip • Iliolumbar ligament (Fig. 21.2) • Anterior sacroiliac ligament • Sacrum—lateral part of upper surface
Insertion	Lesser trochanter of femur	• Iliopectineal eminence • Pecten pubis	• Tendon of psoas major • Lesser trochanter of femur • Small area below lesser trochanter
Nerve supply	Ventral rami of spinal nerves L1, L2, L3	Branch from spinal nerve L1	Femoral nerve
Action	• Flexion of thigh at hip joint • Flexion of lumbar part of vertebral column • Balances trunk in standing	Weak flexor of lumbar vertebral column	• Flexion of thigh (hip joint) • Flexion of lumbar part of vertebral column

the muscle is related to the sympathetic trunk. The lumbar arteries and veins lie between the tendinous arches (which give origin to the muscle) and the vertebral bodies. The medial margin of the right psoas major lies a little lateral to the abdominal aorta.

The ***pelvic part*** of the muscle is related anteriorly to the external iliac artery, gonadal vessels and genitofemoral nerve.

The femoral nerve is related to the lateral margin of the muscle. The right psoas major is crossed by the terminal part of the ileum. The left psoas major is crossed by the terminal part of the descending colon.

The ***femoral part*** of the muscle lies inferior to the inguinal ligament. It lies in front of the hip joint from which it is separated by a huge bursa. It is related laterally to the iliacus, the femoral nerve intervening between the two; and medially to the pectineus. The femoral artery lies in front of the muscle.

Iliacus: The iliacus passes from the abdomen to the thigh (along with the psoas major) lying behind the inguinal ligament and in front of the hip joint. It is related anteriorly to the lateral cutaneous nerve of thigh and, by its medial margin, to the femoral nerve. In the abdomen, the muscle of the right side is related anteriorly to the caecum, and the muscle of the left side to the descending colon.

Iliopsoas: Most of the fibres of iliacus join the tendon of psoas major. Therefore, it is customary to refer to the two mucles together as the iliopsoas. The psoas, developmentally, is part of the iliacus that has migrated above the iliac crest. The iliopsoas, which is inserted into a traction epiphysis (the lesser trochanter of femur), is the chief flexor of the thigh and a stabilizer of the hip joint. Though the iliacus and psoas share hip flexion, only the psoas can produce movement of the lumbar vertebral column.

Quadratus Lumborum (Fig. 21.2)

The quadratus lumborum is so called because of its quadrilateral shape. It forms the bulk of the posterior abdominal wall between the psoas major medially and the transversus abdominis laterally. It is enclosed between the anterior and middle layers of the thoracolumbar fascia. Just below its upper end, the quadratus lumborum is crossed by the lateral arcuate ligament, which gives origin to part of the diaphragm. The part of the quadratus lumborum above the ligament is, therefore, covered by the diaphragm. On both sides (right and left), the quadratus lumborum muscle is related anteriorly to the lower part of the corresponding kidney and subcostal nerves and vessels. The ilioinguinal nerve and the iliohypogastric nerve intervene between the muscle and the kidney. The right and left muscles are related to the ascending and descending colon respectively.

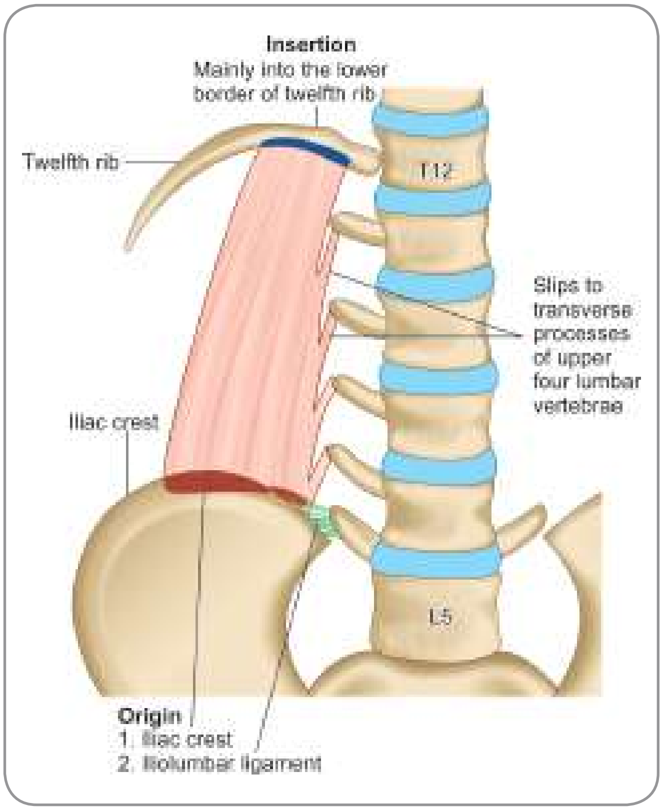


Fig. 21.2: Scheme to show attachments of the quadratus lumborum muscle

Development

Development of Posterior wall Muscles and Fascia

The myotomes of the thoracic and lumbar regions undergo differential growth. By the fifth week, the myotomes get subdivided into a smaller dorsal portion (epimere) and a larger ventrolateral portion (hypomere). As a sequelae, the spinal nerve splits into a dorsal ramus and a ventral ramus in conformity with the split of the myotome. The two primary rami of a spinal nerve are thus formed. Sclerotomic tissue then extends between the epimere and the hypomere; this develops into the transverse processes of the vertebrae. Nervous and osseous changes separate the epimeres and hypomeres further; the mesenchymatous tissue left between them forms a fascial sheet; this fascial sheet becomes an intermuscular septum separating the dorsal division of the musculature from the ventrolateral musculature. This fascia is the first intermuscular septum of the body and forms the primitive lumbar fascia.With further development and sclerotomic moulding of the vertebral column, the epimeres divide further into a medial and a lateral group. The medial group gives rise to the semispinalis-multifidus-rotatores group of muscles. The lateral group develops into the iliocostalis-longissimus-splenius group of muscles. The lower lumbar myotomes are slightly different. Their dorsal portions undergo the same changes as those of the thoracic myotomes. The ventral portions are much smaller, do not extend in the anterolateral body wall and give rise to the psoas and quadratus lumborum.

Clinical Correlation

Psoas Test

The right side psoas major is irritated in the case of acute appendicitis of a retrocaecal appendix. To minimise the pain, the right thigh is held in a flexed position. On extending the thigh, severe pain is experienced by the patient.

Psoas Abscess

Tubercular infection of thoracic or lumbar vertebrae (commonly seen a few decades ago) can lead to formation of pus. As the bodies of the lumbar vertebrae are closely related to the psoas major, this pus passes into the potential space deep to the fascia enclosing the muscle. It then descends along the fascia to reach the femoral triangle where it forms a swelling. Such a swelling may sometimes be confused with a femoral hernia.

VESSELS OF THE POSTERIOR ABDOMINAL WALL

The posterior abdominal wall lodges many important vessels including the abdominal aorta and the inferior vena cava.

Arteries

Abdominal Aorta

The abdominal aorta is a continuation of the descending thoracic aorta. Its upper end lies at the level of the lower border of the 12th thoracic vertebra and behind the median arcuate ligament. It descends in front of the upper three lumbar vertebrae and terminates in front of the 4th lumbar vertebra by dividing into the right and left common iliac arteries.

Relations

The abdominal aorta is related posteriorly to the upper four lumbar vertebrae, the lumbar arteries (that arise from the posterior aspect of the aorta) and some lumbar veins which lie between the aorta and the vertebral column. Anteriorly, it is related to its own branches, namely the coeliac trunk, the superior mesenteric artery, the right and left testicular or ovarian arteries and the inferior mesenteric artery.

Anterior to the coeliac trunk are the papillary process of the liver, the lesser omentum and part of the cavity of the omental bursa. Anterior to the superior mesenteric artery are the pancreas and the splenic vein. The left renal vein runs across the aorta just below the origin of the superior mesenteric artery. A part of the pancreas called the ***uncinate process*** lies deep to this artery. Between the origins of the testicular (or ovarian) and inferior mesenteric arteries, the aorta is crossed by the horizontal (or 3rd) part of the duodenum and by the root of the mesentery. The lowest part of the aorta is covered by the peritoneum lining the posterior abdominal wall. On either side of the aorta

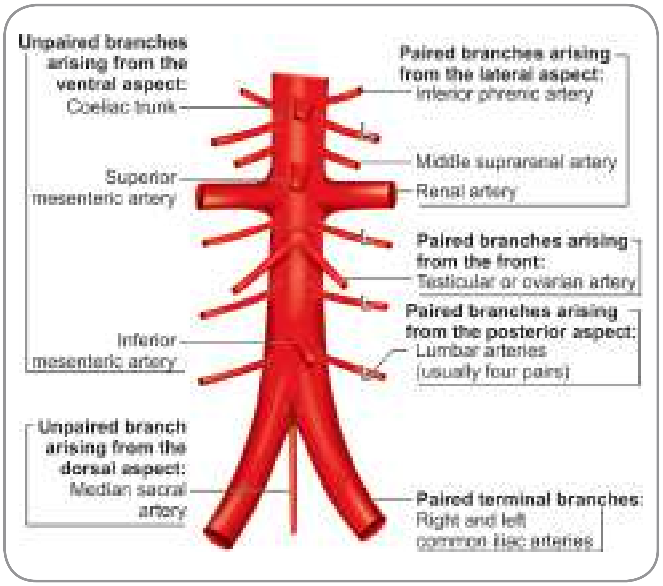


Fig. 21.3: Branches of the abdominal aorta

are the corresponding crus of the diaphragm, the coeliac ganglion and the sympathetic trunk. Additional structures present on the right side of the abdominal aorta are the azygos vein, the thoracic duct and the inferior vena cava.

Branches

The branches of the abdominal aorta can be classified as follows (Fig. 21.3):

- ***Ventral branches*** to the gut:
  - Coeliac,
  - Superior mesenteric, and
  - Inferior mesenteric.
- ***Lateral branches*** to:
  - Kidneys,
  - Suprarenals,
  - Gonads, and
  - Diaphragm.
- ***Dorsal branches*** to the body wall:
  - Lumbar arteries, and
  - Median sacral artery.
- ***Terminal branches:***
  - Common iliac arteries

The ***ventral branches*** of the abdominal aorta have been considered in detail in the Chapter on blood vessels of stomach, intestines, liver, pancreas and spleen. The other branches are considered herewith:

Lateral branches

The most important of these are the ***renal arteries*** and the ***arteries to the testes or ovaries***. In addition, there are two smaller pairs of arteries, namely the ***inferior phrenic*** and the ***middle suprarenal arteries*** (Fig. 21.4).

Dissection

When the rest of the structures of the abdominal cavity have been studied, focus can be shifted to the posterior abdominal wall. After the kidneys and the ureters have been studied, the rest of the structures can be studied. Identify the lumbar sympathetic trunks. Try to trace some of the prevertebral autonomic plexuses. Clean the connective tissue around the aorta. Trace the various branches of the aorta. Clean the inferior vena cava and locate its tributaries. After the vessels and the plexuses are cleaned and studied, turn your attention to the muscles. Locate the psoas and quadratus lumborum. Note their prominent placement. Identify the various vessels, cisterna chyli and azygos vein.

- ***Inferior phrenic arteries:*** The right and left inferior phrenic arteries (Fig. 21.4) arise from the uppermost part of the abdominal aorta. One or both of them may arise from the coeliac trunk. The left artery passes laterally deep to the oesophagus while the right artery passes laterally deep to the inferior vena cava. They divide into a number of branches which ramify on the inferior surface of the diaphragm and supply it.

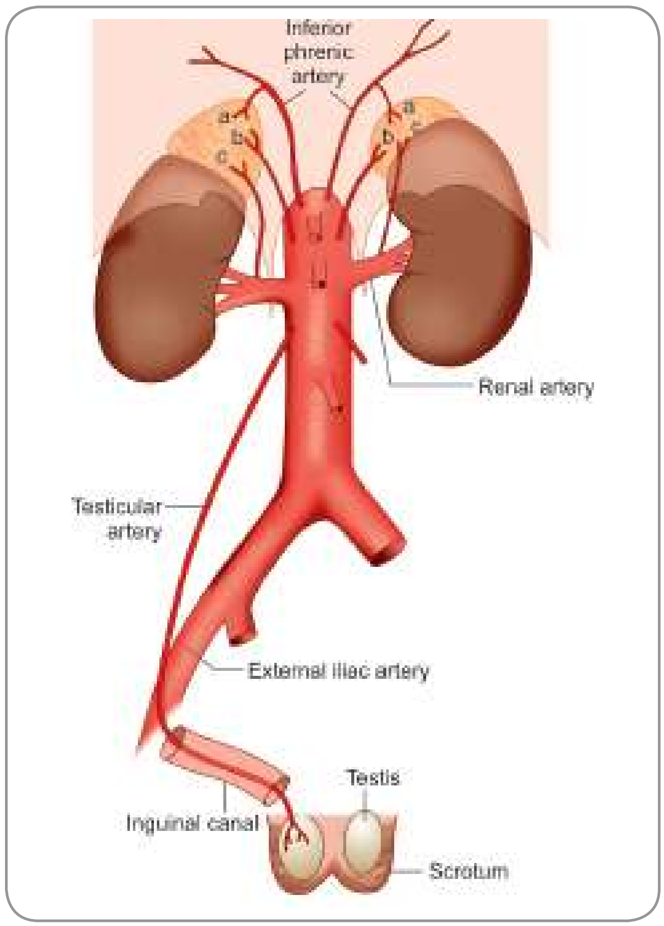


Fig. 21.4: Scheme to show the lateral branches of the abdominal aorta
Key: a. Superior **b.** Middle and **c.** Inferior suprarenal arteries

Each artery gives a superior suprarenal branch to the corresponding suprarenal gland.

- ***Middle suprarenal arteries:*** The middle suprarenal arteries (Figs 21.3 and 21.4) arise from the aorta at the level of the origin of the superior mesenteric artery and end in the corresponding suprarenal gland.
- ***Renal arteries:*** The renal arteries arise from the lateral side of the abdominal aorta, a little below the origin of the superior mesenteric artery (Fig. 21.4). The right artery is a little longer, and a little higher, than the left renal artery. The right renal artery passes posterior to the inferior vena cava, right renal vein, head of pancreas and second part of duodenum. The left renal artery, usually given out a little lower than the right, crosses the left crus of diaphragm and passes posterior to the left renal vein, body of pancreas and splenic vein. As each renal artery passes to the corresponding renal hilum, it gives an ***inferior suprarenal branch***, a branch to the ureter and multiple smaller branches which supply the perirenal tissues, renal capsule and the pelvis. Near the hilum of each kidney, the corresponding renal artery divides into anterior and posterior divisions. Within the renal sinus, these divide further into primary branches, each of which supplies a specific region of renal tissue, there being no anastomoses between arteries to adjoining regions. These primary branches are called ***segmental arteries***. Each segmental artery supplies a discrete area of the kidney, and the pattern of distribution is fairly constant. This allows the kidney to be divided into a number of arterial segments.
- ***Testicular arteries:*** The right and left testicular arteries arise from the abdominal aorta a little below the renal arteries. Each artery runs downwards and laterally over the posterior abdominal wall to reach the external iliac artery. The artery runs downwards along the external iliac artery to reach the internal inguinal ring. It passes through the inguinal canal as a constituent of the spermatic cord and accompanies the cord into the scrotum. Here it divides into branches which supply the testis (Fig. 21.4).
- ***Ovarian arteries:*** Like the testicular arteries, the ovarian arteries arise from the aorta a little below the renal arteries. The upper part of each artery (right and left) runs downwards and laterally over the posterior abdominal wall (formed here by the psoas major) to reach the external iliac artery. The ovarian artery then crosses the external iliac vessels to enter the true pelvis. Leaving the lateral wall of the pelvis, the ovarian artery passes successively through the suspensory ligament of the ovary, the broad ligament of the uterus and the mesovarium to reach the ovary.

Dorsal branches

These are the ***lumbar arteries*** and the ***median sacral artery***.

- ***Lumbar arteries:*** The lumbar arteries are intersegmental arteries which supply the body wall and are in series with the intercostal and subcostal arteries (Fig. 21.5). Four pairs of lumbar arteries arise from the back of the aorta. There is one pair opposite to each of the upper four lumbar vertebrae. The course of the arteries is variable, but typically each artery runs laterally and backwards on the body of the vertebra. It passes deep to the crus of the diaphragm (upper arteries only), the psoas major and the quadratus lumborum. At the lateral border of the quadratus lumborum, the artery enters the interval between the internal oblique and the transversus abdominis. They end by supplying the anterior abdominal wall and anastomose with other arteries of the region.
- ***Median sacral artery:*** The median sacral artery is a small vessel (Fig. 21.5). It arises from the back of the aorta just above the bifurcation of the latter. It descends in the midline over the lower two lumbar vertebrae, the sacrum and the coccyx. It often gives rise to a small pair of ***5th lumbar arteries***. It also gives off four pairs of small arteries which run over the sacrum to enter the anterior sacral foramina. The lower part of the median sacral artery lies behind the rectum to which it gives some branches.

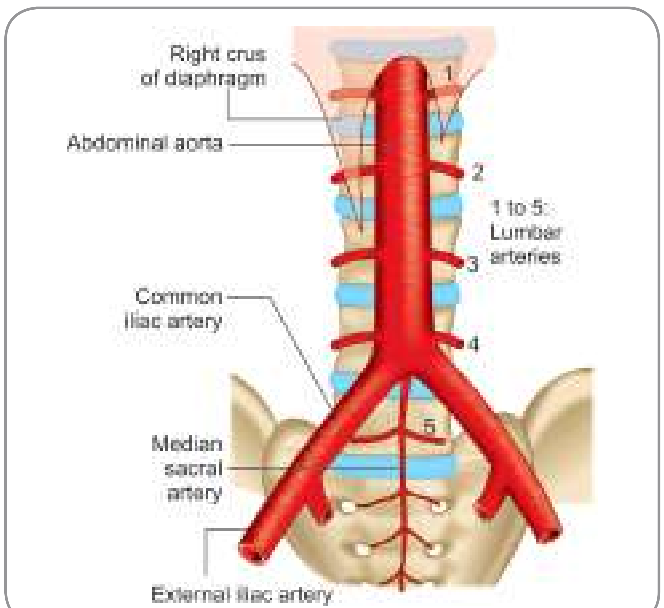


Fig. 21.5: Scheme to show the posterior branches of the abdominal aorta

Key: 1 to 4. Lumbar arteries arising from aorta **5.** 5th lumbar artery arising from median sacral artery

Clinical Correlation

Atherosclerosis of Aorta

As the age of an individual advances, the walls of the arteries undergo degenerative changes. The walls become thicker because of deposition of fatty substances in them. This process is called ***atheroma***. Prominent atheromatous deposits may take place in the aorta, thus making its walls rough and reducing its lumen. Such changes, if at the bifurcation of the aorta, can greatly reduce blood supply to the lower limbs. The patient then has pain in the legs while trying to walk. This condition is called ***claudication***. Lack of blood flow into the internal iliac arteries can lead to impotence. The bifurcation of the aorta can also be blocked by an embolus. In suitable cases, blockage arising from these causes can be corrected by appropriate surgical techniques. An operation for removal of the thickened lining of an artery is called ***endarterectomy***. Removal of a thrombus is called ***thromboendarterectomy***. In some cases, segments of the aorta may have to be replaced or bypassed using synthetic grafts. Atheromatous disease can also lead to the formation of an ***aneurysm*** (dilatation of the wall) of the aorta.

Aortic Aneurysm

This occurs due to the weakening of the wall of the aorta as a result of long-standing atherosclerosis. The aneurysm may present as a palpable, pulsatile mass below the umbilicus.

Angiography

This is a procedure of visualising the blood vessels. Angiography of the aorta is called ***aortography***. A suitable radio-opaque dye, injected into the femoral artery under high pressure, enters the aorta (against the direction of blood flow) and outlines the aorta. A more sophisticated method is to introduce a catheter into the femoral artery and pass it up to the aorta. The tip of the catheter can be guided into a large branch, e.g. the coeliac trunk and dye can be injected directly into the corresponding artery or its branches. After a short interval, the dye passes into venous blood (called the ***venous-filling phase***) and the veins are then visualised.

Terminal branches

The abdominal aorta ends at the lower border of the L4 vertebra by dividing into the right and left common iliac arteries.

- ***Common iliac arteries:*** The right and left common iliac arteries are terminal branches of the abdominal aorta (Fig. 21.5). Each of these arteries is about 4 cm long. The artery of the right side is slightly longer than the left. Each common iliac artery runs downwards and laterally and terminates by dividing into the external and internal iliac arteries.

Each common iliac artery begins in front of the body of the 4th lumbar vertebra, a little to the left of the median plane (Fig. 21.5). It terminates in front of the sacroiliac joint, at the level of the disc between the 5th lumbar vertebra and the sacrum. It is related posteriorly to the bodies of the 4th and 5th lumbar vertebrae and to the disc between them.

The union of the right and left common iliac veins to form the inferior vena cava lies below and to the right of the bifurcation of the aorta; and the veins lie posterior to the corresponding arteries. The right common iliac artery is related posteriorly to both the common iliac veins and to the beginning of the inferior vena cava. The vena cava and the right common iliac vein are lateral to its upper part, while the left common iliac vein is medial to its upper part. The left common iliac vein is partly medial to and partly behind the left common iliac artery (Fig. 21.6).

These arteries are covered in front by peritoneum that separates them from the coils of small intestine. Each artery is crossed by the ureter, just near its termination (Fig. 21.7). The left common iliac artery is crossed by the superior rectal artery. Both (right and left) common iliac arteries are crossed by sympathetic nerve fibres going to the superior hypogastric plexus (Fig. 21.7). The arteries are related laterally to the psoas major. Deep in the interval between the 5th lumbar vertebra and the psoas major, two

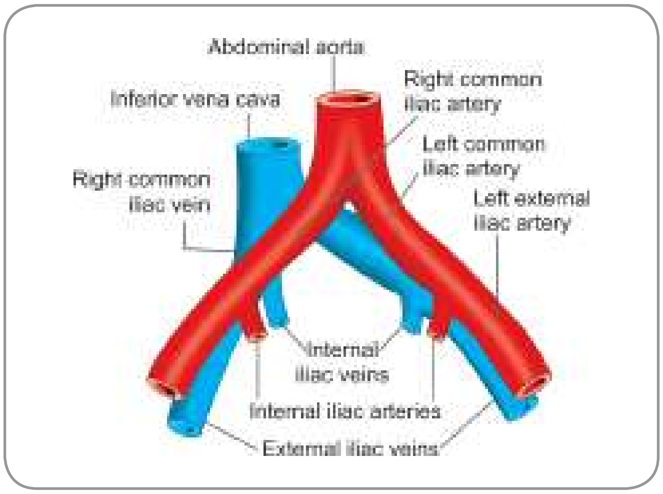


Fig. 21.6: Relationship of right and left common iliac arteries and veins to one another

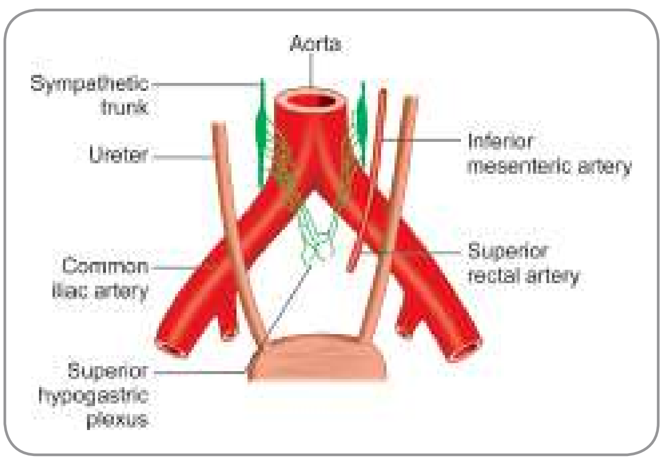


Fig. 21.7: Anterior relations of common iliac arteries

important nerves, the lumbosacral trunk and the obturator nerve lie behind the artery.

- ***External iliac arteries:*** The external iliac arteries begin at the bifurcation of each common iliac artery. They run downwards and laterally and terminate deep to the inguinal ligament. Each artery is continued into the corresponding thigh as the femoral artery. Each artery is related posterolaterally to the psoas major muscle, and posteromedially to the corresponding external iliac vein. It is covered anteriorly and medially by peritoneum that separates it from the coils of intestine.

The external iliac artery is crossed by a number of structures as follows:

- Near its beginning, the artery may be crossed by the ureter (and in the female by the ovarian artery).
- The distal part of the vessel is crossed obliquely by the testicular artery (in the male) and by the genital branch of the genitofemoral nerve.
- Near its termination, it is crossed in the male by the ductus deferens; and in the female by the round ligament of the uterus.

On the right side, the artery is crossed by the terminal ileum and frequently by the vermiform appendix. On the left side, it is crossed by the sigmoid colon.

- ***Branches of external iliac artery:*** The branches of the external iliac artery are the inferior epigastric and the deep circumflex iliac arteries. They are intimately related to the anterior abdominal wall.
- ***Internal iliac arteries:*** Each internal iliac artery (right or left) begins as a terminal branch of the common iliac artery, in front of the sacroiliac joint (Fig. 21.5). The artery is distributed mainly within the pelvis and will be considered in the chapter on Pelvis.

Veins

Inferior Vena Cava and its Main Tributaries

Various structures in the abdomen, pelvis and lower limbs are drained by the inferior vena cava. This is the largest vein in the body. It lies on the posterior abdominal wall to the right of the abdominal aorta. It is formed by the union of the right and left common iliac veins (Fig. 21.8). It ends by piercing the diaphragm to open into the right atrium of the heart.

The common iliac veins are formed by the union of the internal and external iliac veins. These veins run along the corresponding arteries. Each external iliac vein begins behind the inguinal ligament as the continuation of the femoral vein. The femoral vein drains the lower limb and lies alongside the femoral artery.

Relations

The upper part of the vena cava rests on the right crus of the diaphragm. The lower part of the vena cava lies on the 3rd, 4th and 5th lumbar vertebrae. The diaphragm is separated from the vessel by a part of the right suprarenal gland and by the right coeliac ganglion. Lateral to the 3rd, 4th and 5th lumbar vertebrae, the vena cava lies on the medial margin of the right psoas major. The right sympathetic trunk descends behind the vena cava. Several arteries arising from the aorta and passing to the right cross behind the vena cava. These are the:

- Right renal artery,
- Right inferior phrenic artery,
- Right suprarenal artery, and
- Third and fourth right lumbar arteries.

The anterior relations of the inferior vena cava are shown in Figure 21.9. The vena cava is overlapped (from above downwards) by the:

- Liver,
- Epiploic foramen which separates it from the right free margin of the lesser omentum,
- Superior part of duodenum,
- Head of pancreas,
- Horizontal part of duodenum,
- Root of mesentery containing the superior mesenteric artery and vein, and

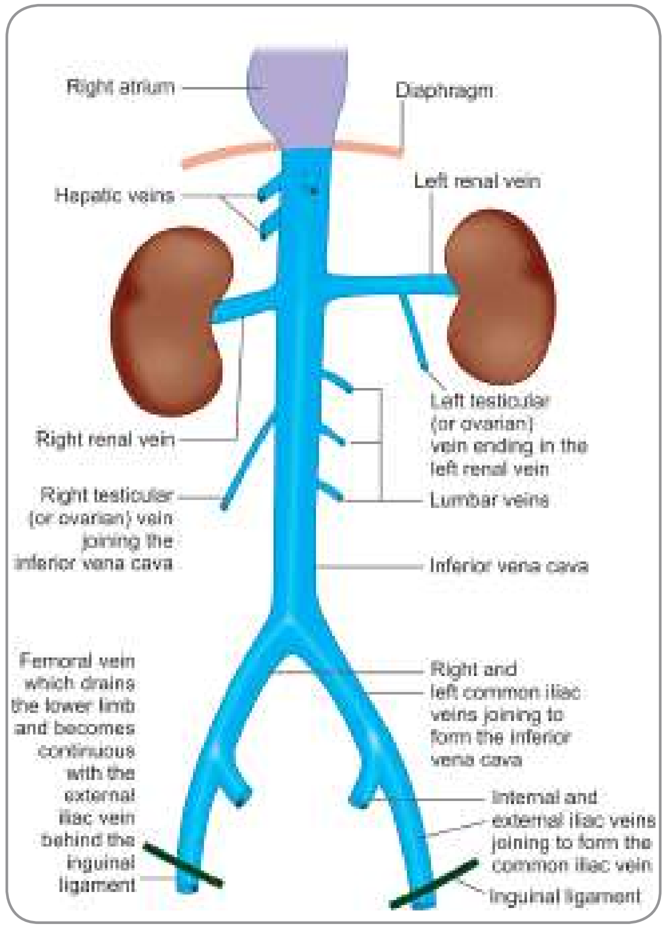


Fig. 21.8: Scheme to show the inferior vena cava and its tributaries

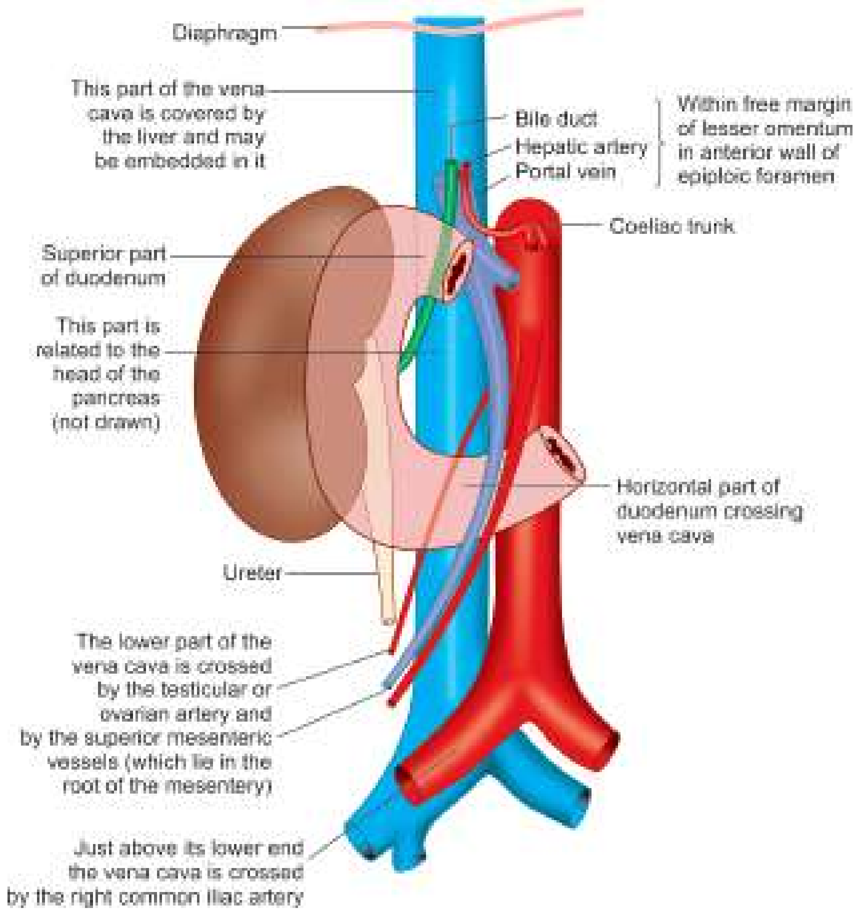


Fig. 21.9: Scheme to show the anterior relations of the inferior vena cava

- Right common iliac artery.

Other structures anterior to the vessel are as follows:

- The portal vein and the bile duct lie between the vena cava and the superior part of the duodenum.
- Higher up, the portal vein, bile duct and hepatic artery lie in the free margin of the lesser omentum. They are separated from the vena cava by the epiploic foramen.
- The right testicular or ovarian artery crosses the vena cava descending obliquely between it and the horizontal part of duodenum.

Direct Tributaries

The largest tributaries of the inferior vena cava are the hepatic veins from the liver and the renal veins from the kidneys.

- The ***hepatic veins*** are terminal parts of an elaborate venous tree that permeates the liver. They emerge from the liver tissue that is in close contact with the upper part of the vena cava and immediately enter into the latter. The cut ends of the veins are seen on the vena cava when the liver is removed (Fig. 21.8).
- The right and left ***renal veins*** run horizontally from the hila of the kidneys to join the inferior vena cava. The right vein is about 2.5 cm long. It lies behind the descending part of the duodenum. The left renal vein is much longer (7.5 cm) than the right vein as it has to cross the midline to reach the vena cava. The left renal vein crosses anteriorly to the aorta and posteriorly to the body of pancreas and splenic vein.

  From a developmental point of view, part of the left renal vein is homologous to a segment of the inferior vena cava near the termination of the renal veins. It, therefore, happens that some veins of the right side open into the inferior vena cava, but the corresponding veins of the left side end in the left renal vein. These veins are as follows (Fig. 21.10):
  - The ***inferior phrenic veins*** which accompany the corresponding arteries; the vein of the right side ends in the inferior vena cava and the vein of the left side usually ends in the left renal vein.
  - The ***suprarenal veins*** which emerge from the hila of the suprarenal glands; the vein of the right side

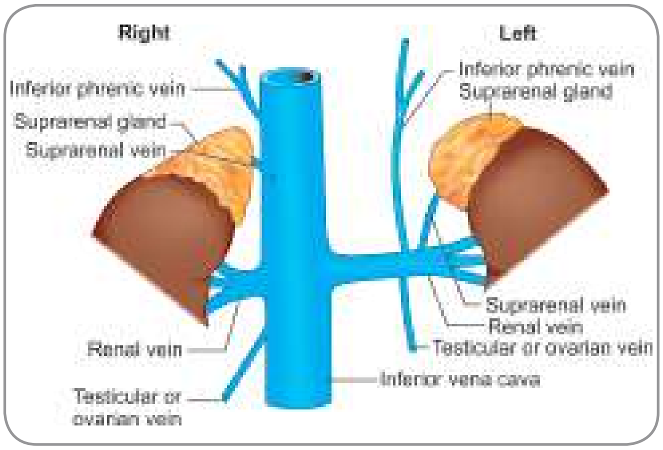


Fig. 21.10: Scheme to show some veins that open on the right side into the inferior vena cava and on the left side into the left renal vein

opens into the back of the inferior vena cava and that of the left side opens into the left renal vein.

- The ***testicular vein*** (in the male) that travels through the spermatic cord and the inguinal canal in the form of a plexus (called the ***pampiniform plexus***); at the deep inguinal ring, two veins emerge from this plexus and run over the lower part of the posterior abdominal wall along with the testicular artery; higher up they unite to form a single trunk that opens on the right side into the inferior vena cava and on the left side into the left renal vein.
- The ***ovarian veins*** (in the female) that form a plexus in the broad ligament; two veins arising from the plexus accompany the ovarian artery; higher up they unite to form one vein that terminates in a pattern similar to that of the testicular vein.

- The ***lumbar veins*** accompany the lumbar arteries (Fig. 21.11). There are four of them on either side. They drain blood from the abdominal wall and from the vertebral venous plexuses. In front of the roots of the transverse processes of the lumbar vertebrae, the lumbar veins communicate with each other by a vertical venous channel called the ***ascending lumbar vein***. Parallel and medial to the ascending lumbar vein is another vertical vein called the ***lumbar azygos vein***. The 1st and 2nd lumbar veins may end in the ascending lumbar vein or in the lumbar azygos vein; or more rarely in the inferior vena cava. The 3rd and 4th lumbar veins usually end in the inferior vena cava. The mode of termination of the lumbar veins is subject to considerable variation (Fig. 21.11).

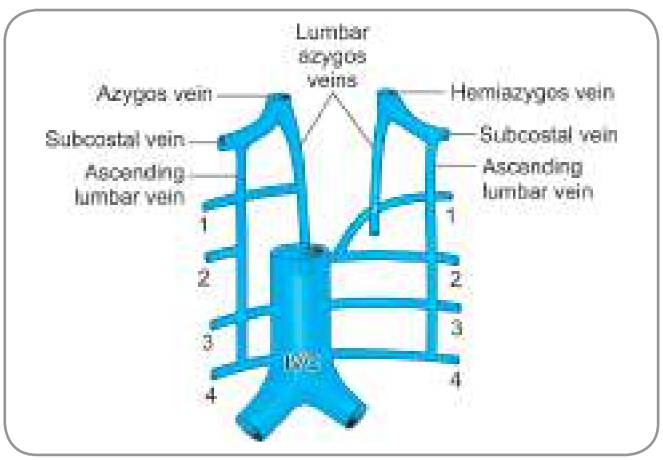


Fig. 21.11: Scheme to show the lumbar veins (1 to 4). They may end in the inferior vena cava (IVC), in the ascending lumbar vein, or in the lumbar azygos vein

Clinical Correlation

Congenital Anomalies

The inferior vena cava has a complicated developmental history and, therefore, various anomalies may be seen. In the embryo, the vena cava is a paired structure that normally persists only on the right side. Persistence on both sides results in a ***double inferior vena cava***. Generally, the duplication is confined to the part below the level of the renal arteries (infrarenal segment). Sometimes, the infrarenal segment may persist only on the left side (instead of the right) leading to a ***left inferior vena cava***. Sometimes, the part of the inferior vena cava related to the stomach (hepatic segment) may be missing. The vena cava is then continuous with a much enlarged azygos vein through which it drains into the superior vena cava (***azygos continuation of inferior vena cava***). Normally, the inferior vena cava lies behind the right ureter. However, it may lie in front of the ureter.

Obstruction

The inferior vena cava may be obstructed by the formation of a thrombus. It may also be obstructed by pressure from a malignant growth. Obstruction leads to oedema in the lower limbs. When the inferior vena cava is obstructed, communication between tributaries of the inferior vena cava and those of the superior vena cava becomes important, and can undergo considerable enlargement. The inferior epigastric, circumflex iliac and external pudendal veins are invariably involved. Blood from them passes into the lateral thoracic, internal thoracic and posterior intercostal veins. Superficial channels of communication become prominent over the abdominal wall. The ***thoracoepigastric vein*** is an important channel of communication. Communication between the superior and inferior venae cavae is also established through the azygos and hemiazygos system of veins and through the vertebral venous plexus. In pregnancy, the inferior vena cava may be pressed upon by the enlarged uterus, and this may lead to oedema in the dependent parts of the lower limb.

Common Iliac Veins

Each common iliac vein (right and left) is formed by the union of the corresponding internal and external iliac veins. This union takes place in front of the sacroiliac joint. From here, the common iliac vein passes upwards and medially and ends by joining the vein of the opposite side

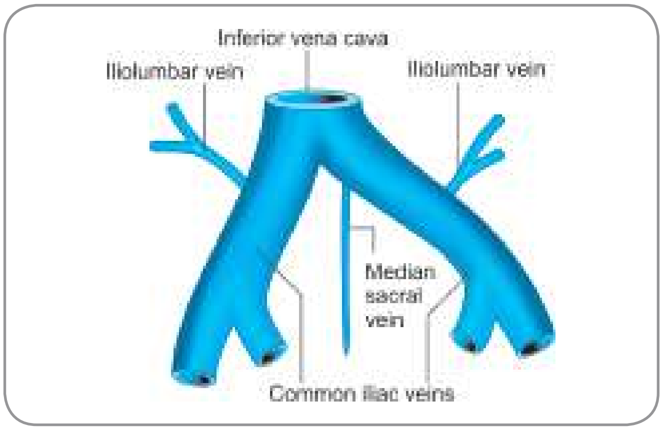


Fig. 21.12: Tributaries of common iliac veins

to form the inferior vena cava (in front of the 5th lumbar vertebra). As the lower end of the inferior vena cava lies to the right of the middle line, the right common iliac vein has to follow a shorter and more vertical course than the vein of the left side.

Relations

The lower part of the right common iliac vein is behind the corresponding artery and higher up, it becomes lateral to the artery. The left common iliac vein is medial to the corresponding artery over the greater part of its course. Its terminal part is behind the right common iliac artery. The left common iliac vein is crossed by the superior rectal artery and vein as they run through the root of the transverse mesocolon.

The tributaries of the common iliac veins are shown in Figure 21.12. The iliolumbar and median sacral veins accompany the corresponding arteries.

External Iliac Veins

Each external iliac vein begins behind the corresponding inguinal ligament as a continuation of the femoral vein. It runs upwards and medially along the brim of the pelvis. It ends in front of the sacroiliac joint by joining the internal iliac vein to form the common iliac vein. The vein is medial to the corresponding artery (Fig. 21.13), but near its upper end, it becomes posterior to the artery and passes behind the internal iliac artery. Along with the external iliac artery, the vein rests on the psoas major. The right and left veins are crossed by the same structures which cross the corresponding arteries.

On both sides, the vein is crossed (from above downwards) by:

- The internal iliac artery (Fig. 21.13),
- The ureter,
- The testicular or ovarian artery, and
- The ductus deferens (or in the female, the round ligament of the uterus).

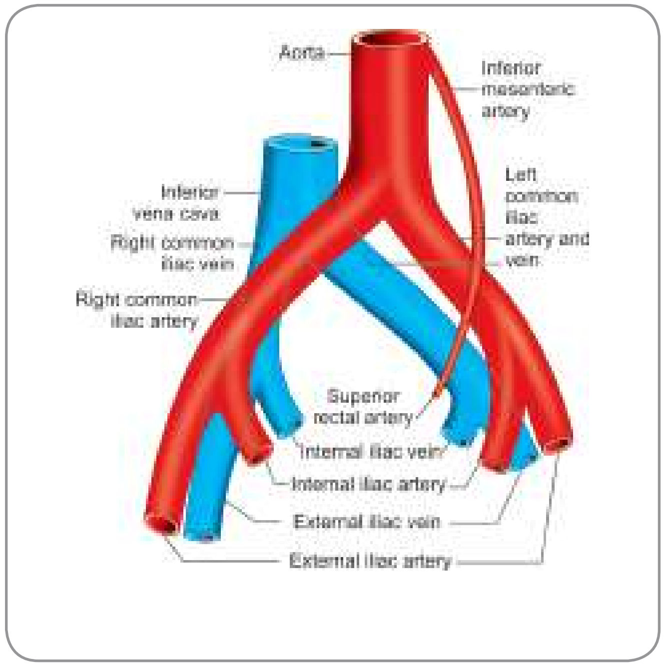


Fig. 21.13: Relations of common iliac veins

On the right side, it is also crossed (in addition to the above) by the terminal part of the ileum and sometimes by the vermiform appendix. On the left side, the vein is also crossed by the sigmoid colon.

The tributaries of the external iliac veins are:

- The inferior epigastric vein,
- The deep circumflex iliac vein, and
- The pubic veins.

These veins run along the corresponding arteries.

Internal Iliac Veins

The internal iliac veins are veins of the pelvis and will be considered in the chapter on pelvis.

NERVES OF POSTERIOR ABDOMINAL WALL

The posterior abdominal wall contains several nerves.

Just below the 12th rib, the ***subcostal nerve*** is ***present***. This nerve is a continuation of the ventral ramus of the 12th thoracic spinal nerve.

Most of the other nerves seen are branches of the lumbar plexus. This plexus is formed by the ventral rami of lumbar spinal nerve within the substance of the psoas major muscle. This plexus is concerned mainly with the innervation of the lower limb and has been dealt with in detail in the section on lower limb. The branches of the lumbar plexus seen on the posterior abdominal wall are:

- The iliohypogastric nerve,
- The ilioinguinal nerve,
- The genitofemoral nerve,
- The lateral cutaneous nerve of thigh, and

- The femoral nerve.

The autonomic plexuses and ganglia which are closely related to the aorta are also located on the posterior abdominal wall.

AUTONOMIC INNERVATION OF ABDOMINAL AND PELVIC VISCERA

The abdominal and pelvic viscera receive autonomic innervation, which is both sympathetic and parasympathetic. The preganglionic sympathetic and parasympathetic fibres are transmitted to the abdominal aortic plexus and associated ganglia by several splanchnic nerves and one cranial nerve (the vagus). The sympathetic fibres relay in the prevertebral sympathetic ganglia and the postganglionic fibres pass through the various periarterial extensions of the aortic plexus to the viscera. The parasympathetic fibres continue without relay to the viscera where they relay in the intrinsic parasympathetic ganglia.

Autonomic Ganglia and Plexuses

The ***abdominal autonomic plexuses*** are nerve networks which surround the abdominal aorta and its major branches. They contain both sympathetic and parasympathetic fibres. Though they are called ***plexuses***, they contain numerous neurons and are, in fact, equivalent to ganglia. The ganglia so formed are the ***prevertebral sympathetic ganglia***.

The ***coeliac ganglion*** (right or left) is the largest autonomic ganglion in the body. It is irregular in shape. Its lower part is often separate from the rest of the ganglion and is called the ***aorticorenal ganglion***. The coeliac ganglion lies on the posterior abdominal wall, in front of the corresponding crus of the diaphragm. Just medial to it is the abdominal aorta (at the level of origin of the coeliac trunk), and just lateral to the ganglion is the suprarenal gland. The right coeliac ganglion lies behind the inferior vena cava and the left ganglion lies behind the splenic vessels. Fibres passing from one ganglion to the other (across the aorta and around the origin of the coeliac trunk) form the ***coeliac plexus***. The ***coeliac ganglia*** and ***coeliac plexus*** lie in relation to the abdominal aorta at the level of the origin of the coeliac trunk. The coeliac plexus receives sympathetic fibres through the sympathetic roots which are the greater and lesser splanchnic nerves and parasympathetic fibres through the parasympathetic root which is a branch of the posterior vagal trunk.

The coeliac plexus is the uppermost part of an extensive ***aortic plexus*** surrounding the abdominal aorta. This is continued into subsidiary plexuses around the branches arising from the vessel. The superior mesenteric plexus and ganglia surround the origin of the superior mesenteric artery. There are three roots to this plexus—one median and two lateral. The median root is a branch from the coeliac plexus and the lateral roots are branches from the lesser and least splanchnic nerves. The inferior mesenteric plexus surrounds the inferior mesenteric artery and usually has an inferior mesenteric ganglion. It receives a medial root from the intermesenteric plexus and two lateral roots from the lumbar ganglia of the sympathetic trunks.

The part of the aortic plexus between the origins of the superior and inferior mesenteric arteries is called the ***intermesenteric plexus***. It gives rise to subsidiary plexuses ***renal***, ***testicular*** or ***ovarian*** and ***ureteric plexuses***.

The part overlying the bifurcation of the aorta is called the ***superior hypogastric plexus***. It gives twigs to the ureteric and testicular plexuses.

When traced downwards, the lower part of the aortic plexus divides into the right and left ***inferior hypogastric plexuses*** related to the corresponding internal iliac arteries. The two inferior hypogastric plexuses (which actually lie around the urinary bladder, uterus and rectum) are connected to the superior hypogastric plexus by the right and left hypogastric nerves. They receive branches from the superior sacral sympathetic ganglia and the pelvic parasympathetic splanchnic nerves. Extensions of the inferior hypogastric plexus surround the blood vessels and form visceral plexuses like the ***vesical plexus*** (surrounding the urinary bladder) and ***rectal plexus*** (surrounding the rectum).

The enteric parasympathetic plexuses are located in the walls of the viscera. These are the ***myenteric plexus*** (of Auerbach) between the muscle coats and the ***submucosal plexus*** (of Meissner) in the submucosa.

Sympathetic Nerves

Lumbar Part of Sympathetic Trunk

The sympathetic trunk passes from the thorax to the abdomen by passing posterior to the medial arcuate ligament. Sometimes it may pass through the crus of the diaphragm. The lumbar trunk lies in the extraperitoneal connective tissue anterior to the vertebral column and medial to the psoas major. Inferiorly, the lumbar sympathetic trunk is continuous with the pelvic sympathetic trunk.

There are usually four ganglia on the lumbar part of the trunk. All the four ganglia give off grey rami communicantes to the lumbar spinal nerves. The first two ganglia (sometimes three) receive white rami communicantes from the corresponding spinal nerves. These white rami are part of the thoracolumbar outflow carrying preganglionic fibres to the sympathetic trunk. Each ganglion gives off a ***lumbar splanchnic branch***. These branches end in the coeliac, renal, aortic and superior hypogastric plexuses.

Lower Thoracic Splanchnic Nerves

These are the splanchnic nerves which arise from the thoracic sympathetic trunk and pass into the abdominopelvic cavity. The greater splanchnic nerve from the T5 to T10 levels, the lesser splanchnic nerve from the T10 to T11 levels and the least splanchnic nerve from the T12 level pierce the corresponding crus of the diaphragm and enter the abdominal cavity. They then run to the various parts of the aortic plexus.

Lumbar Splanchnic Nerves

These are the splanchnic nerves which arise from the lumbar sympathetic trunk. These nerves pass to the coeliac, renal, aortic and superior hypogastric plexuses.

Sympathetic Part of Abdominal Innervation

The sympathetic part of abdominal innervation consists of the following components:

- Abdominopelvic splanchnic nerves,
- Prevertebral sympathetic ganglia, and
- Abdominal aortic plexus and its extensions.

The abdominopelvic splanchnic nerves (both the lower thoracic and lumbar splanchnic nerves) convey preganglionic sympathetic fibres which arise from the cell bodies in the intermediate horns of the T5 to L2–3 spinal segments (thoracolumbar outflow). These fibres pass successively through the ventral roots, ventral rami, white rami communicantes of the thoracic and upper lumbar spinal nerves and reach the sympathetic trunk. They do not relay in the paravertebral ganglia of the trunks but pass without synapse through the abdominopelvic splanchnic nerves. Through the branches of these splanchnic nerves the preganglionic sympathetic fibres reach the prevertebral sympathetic ganglia present along the various plexuses.

The prevertebral ganglia are present amongst the various plexuses (as described above). The sympathetic fibres relay in these ganglia.

The postganglionic sympathetic fibres arising from the prevertebral ganglia pass through the extensions of the aortic plexus and through the periarterial plexuses (which are connected with the aortic plexus) to reach the concerned viscera.

Sympathetic stimulation causes vasoconstriction and in the digestive tract, results in slowing down of peristalsis.

Visceral Afferent Innervation

Visceral afferent fibres conveying pain sensations accompany the sympathetic fibres (the sympathetic fibres are visceral efferent). Pain impulses pass through the aortic and periarterial plexuses and the splanchnic nerves to the sympathetic trunk. They then pass through the white rami communicantes to the ventral rami of spinal nerves. From here, they pass into the dorsal roots and the dorsal root ganglia and finally reach the spinal cord.

The foregut is subserved by the T6 to T9 levels, the midgut by the T8 to T12 levels and the hindgut by the T12 to L2 levels.

Visceral afferent fibres from below the level of the sigmoid colon travel along with the parasympathetic fibres, pass to the sensory root ganglia of the S2 to S4 levels and then reach the spinal cord. In the spinal cord they reach the spinal segments which are involved in the sympathetic innervation of those viscera.

Parasympathetic Nerves

Craniosacral Outflow—Cranial Part

The parasympathetic nerve fibres are derived from cranial and sacral outflow. In the thorax and abdomen, the cranial outflow is represented by the vagus nerve. In the thorax, fibres of both the vagi (left and right) form an anterior and a posterior oesophageal plexus. Fibres emerging from the lower end of the anterior oesophageal plexus collect to form the ***anterior vagal trunk*** that is made up mainly of fibres of the left vagus nerve. Similarly, fibres arising from the posterior oesophageal plexus (derived mainly from the right vagus) collect to form the ***posterior vagal trunk***. These two trunks enter the abdomen through the oesophageal opening in the diaphragm. They are responsible for the parasympathetic supply to the greater part of the gastrointestinal tract and to some other abdominal organs.

Sacral Outflow

The sacral outflow is formed by the pelvic splanchnic nerves. These are direct branches of the ventral rami of the S2 to S4 spinal nerves and have nothing to do with the sympathetic trunks. They pass to the pelvic viscera and to the inferior hypogastric plexus (also called the ***pelvic plexus***). The preganglionic neurons which constitute the ***sacral parasympathetic outflow*** are located in the intermediolateral grey column of spinal segments S2, S3 and S4. The preganglionic fibres from these neurons emerge from the spinal cord through the ventral nerve roots of the corresponding spinal nerves. They soon leave the spinal nerves through their ***pelvic splanchnic branches***.

Parasympathetic Part of Abdominal Innervation

The parasympathetic part of abdominal innervation consists of the following components:

- Anterior and posterior vagal trunks,
- Pelvic splanchnic nerves,
- Abdominal aortic plexus and its extensions, and
- Intrinsic parasympathetic ganglia

These preganglionic parasympathetic fibres arise from the concerned neurons in the cranial and sacral parts. The fibres from the cranial flow pass through the vagal nerves and reach the various viscera. The fibres from the sacral flow pass through the pelvic splanchnic nerves and reach the aortic plexus and its extensions. The latter fibres do not synapse in the prevertebral ganglia and pass through the periarterial extensions to the various viscera. In the viscera, these fibres (both the cranial and sacral outflow components in the respective viscera) end in relation to the postganglionic neurons which are located either in the walls of the viscera or in the plexuses related to them. The postganglionic fibres arise from these neurons and immediately supply the viscera.

The cranial outflow fibres (vagal fibres) supply the lower oesophagus, stomach, small intestines, ascending colon and most of the transverse colon. The sacral outflow fibres supply the rest of the gut and the pelvic organs.

The organs supplied directly by the pelvic splanchnic nerves are the urinary bladder, rectum, testes or ovaries, uterus, uterine tubes and penis or clitoris. The organs which are subserved by the pelvic splanchnic nerves but through the pelvic plexus are the ***sigmoid colon***, ***descending colon*** and the left one-third of the ***transverse colon***.

Parasympathetic stimulation results in increased peristalsis.

LYMPHATIC STRUCTURES OF POSTERIOR ABDOMINAL WALL

The largest lymph vessel in the body is the ***thoracic duct***. This duct begins in the abdomen as an upward continuation of a sac-like structure called the ***cisterna chyli*** (Fig. 21.14). The cisterna chyli is seen in relation to the posterior abdominal wall. It is an elongated lymphatic sac, about 6 cm long. It is placed vertically in front of the 1st and 2nd lumbar vertebrae. It lies to the right of the abdominal aorta, and deep to the right crus of the diaphragm.

Chief Lymph Nodes of Abdomen and Pelvis

The lymph from the entire abdomen (and from the lower limbs) ultimately ends in terminal groups of lymph nodes present in relation to the abdominal aorta. These nodes are arranged in three main groups, each having a specific area of drainage.

- In front of the aorta are the ***preaortic nodes***. These are divided into the ***coeliac***, ***superior mesenteric*** and ***inferior mesenteric*** nodes lying around the origins of the corresponding arteries. Efferents from the preaortic nodes form the ***intestinal trunk*** that ends in the cisterna chyli.

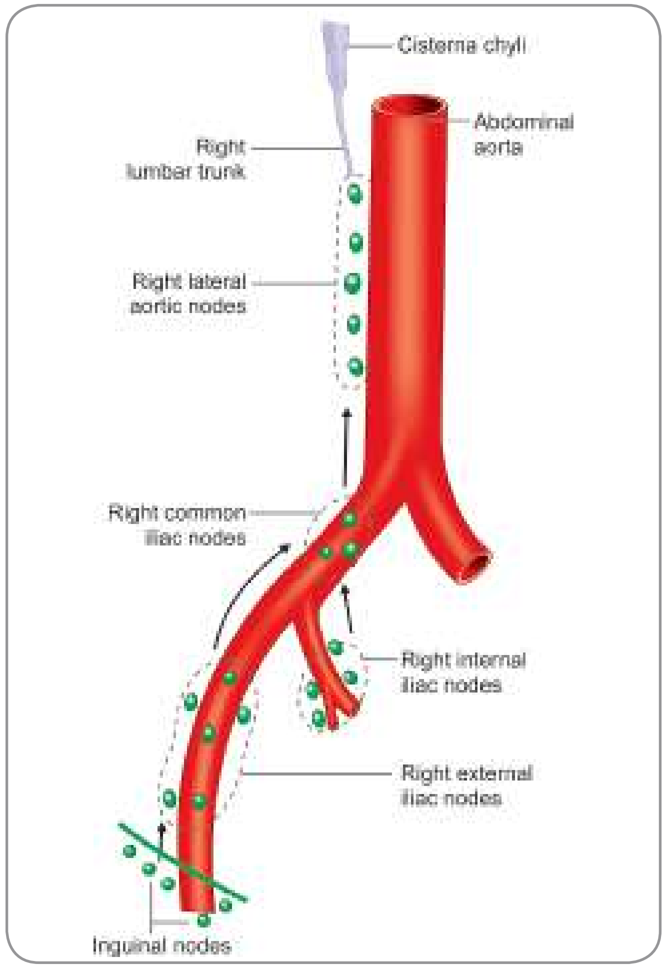


Fig. 21.14: The lateral aortic lymph nodes

The coeliac lymph nodes receive lymph from the:
- Stomach
- Part of the duodenum
- Liver
- Extrahepatic biliary apparatus
- Pancreas
- Spleen.

The superior mesenteric lymph nodes receive lymph from the:
- Jejunum
- Ileum
- Caecum
- Appendix
- Ascending colon
- Transverse colon
- Part of the duodenum.

The inferior mesenteric lymph nodes receive lymph from the:
- Descending colon
- Sigmoid colon
- Upper part of the rectum.

- On either side of the aorta are the right and left ***lateral aortic nodes***. The ***lateral aortic nodes*** receive all the lymph draining through the common iliac nodes. They also receive lymph directly from the:
  - Posterior abdominal wall
  - Kidneys and upper part of the ureters
  - Testes or ovaries
  - Uterine tubes and part of the uterus
  - Suprarenal glands.

  The ***common iliac nodes*** lie along the corresponding blood vessels. They receive lymph from the external and internal iliac nodes and send it to the lateral aortic nodes. The ***internal iliac nodes*** lie along the corresponding blood vessels. They receive most of the lymph of the pelvic organs and lymph from the deeper tissues of the perineum. They also receive some vessels of the lower limbs which travel along the superior and inferior gluteal blood vessels. The ***external iliac lymph nodes*** lie along the external iliac blood vessels. They receive lymph from the lower limb through the inguinal nodes. They also receive direct lymph vessels from the deeper tissues of the infraumbilical part of the anterior abdominal wall and from some pelvic organs.

  Efferents from the lateral aortic nodes form the right and left ***lumbar trunks*** which join the cisterna chyli.
- Some outlying members of these groups lie behind the aorta and constitute the ***retroaortic nodes***.

The retroaortic nodes form a very small group and have no particular area of drainage. They receive small lymphatics of the posterior abdominal wall and provide a link to the adjacent groups of nodes.

Multiple Choice Questions

1. Erector spinae and quadratus lumborum are separated by:
   a. Anterior layer of thoracolumbar fascia
   b. Middle layer of thoracolumbar fascia
   c. Posterior layer of thoracolumbar fascia
   d. Conal fascia

2. The lateral branches of the abdominal aorta are:
   a. Inferior phrenic, renal, gonadal and lumbar arteries
   b. Inferior phrenic, middle suprarenal, lumbar and median sacral arteries
   c. Inferior phrenic, gonadal, lumbar and median sacral arteries
   d. Inferior phrenic, middle suprarenal, renal and gonadal arteries

3. The left inferior phrenic vein drains into the:
   a. Inferior vena cava
   b. Left renal vein
   c. Left inferior mesenteric vein
   d. Left common iliac vein

4. The largest autonomic ganglion of the body is the:
   a. Aorticorenal ganglion
   b. Coeliac ganglion
   c. Prevertebral sympathetic ganglion
   d. Ganglion impar

5. The pelvic plexus is:
   a. Superior hypogastric plexus
   b. Inferior hypogastric plexus
   c. Vesical plexus
   d. Rectal plexus

ANSWERS

1. b **2.** d **3.** b **4.** b **5.** b

Clinical Problem-solving

Case Study 1: The X-ray picture of the lumbar region of a 54-year-old man shows sacralisation.
- What do you understand by the term 'sacralisation'?
- What is the opposite but complementary change called?

Case Study 2: A 67-year-old man complains of pain in the legs on and off. The pain is aggravated while trying to walk.
- What is the name of the condition he is suffering from?
- What is the anatomical basis of this condition?

(For solutions see Appendix).

Chapter **22**

Walls of Pelvis

Frequently Asked Questions

- Discuss the levator ani in detail.
- Write notes on: (a) Pelvic floor, (b) Parietal pelvic fascia.
- Write briefly on: (a) Pudendal nerve, (b) Visceral pelvic fascia.

The walls of the pelvis are made up of the bones and joints, the muscles and fascia, and the blood vessels, nerves and lymphatics of the region. The true pelvis presents anterior, posterior and two lateral walls. It also has a floor that is mainly made up of muscles.

ANTERIOR WALL

The anterior wall is formed by the posterior surface of the pubic symphysis and the adjoining pelvic surfaces of the bodies of the right and left pubic bones. This wall is related to the urinary bladder and is connected to it by the pubo prostatic ligaments in males and pubovesical ligaments in females.

POSTERIOR WALL

The posterior wall is elongated and curved and is formed in the median plane by the pelvic surface of sacrum, coccyx and anococcygeal raphe. The space between the sacrum and the hip bone is bridged by the sacrotuberous and sacrospinous ligaments. As a result, the greater and lesser sciatic foramina are formed. On each side, the posterior wall is formed by the piriformis, coccygeus and levator ani muscles covered by the parietal layer of pelvic fascia. The upper part of posterior wall is covered by parietal peritoneum and is also related to the root of sigmoid mesocolon; the lower part is related to the rectum. Between the posterior wall and the rectum, the following structures are present—median sacral vessels, superior rectal vessels, right and left sympathetic trunks, ganglion impar, glomus coccygeum,sacral plexus of nerves, pelvic splanchnic nerves and lateral sacral vessels.

LATERAL WALL

The lateral wall, on each side, is formed by the pelvic surface of the body and ramus of ischium, both rami of pubis and a small triangular pelvic surface of ilium. The large obturator foramen is covered by the obturator membrane, except in the upper and posterior part where it allows exit of the obturator nerve and vessels. The inner surface of the obturator membrane is covered by the obturator internus muscle, obturator fascia and parietal peritoneum. Structures running obliquely along the lateral pelvic wall from above downwards are as follows—obliterated umbilical artery, obturator nerve and vessels, superior vesical, inferior vesical, uterine, vaginal and middle rectal vessels.

The ureter and internal iliac vessels pass closer to the greater sciatic foramen in the ***posterior part of lateral pelvic wall***, and vas deferens in males and round ligament in females is related to the ***anterior part of lateral pelvic wall***. The urinary bladder apart from being related to the anterior pelvic wall is also related to the lateral wall. In females, the lateral pelvic wall gives attachment to the broad ligament.

PELVIC FLOOR

The pelvic floor is formed by the levator ani and coccygeus muscles of both sides with their covering fasciae. Both muscles form together the pelvic diaphragm, which slopes downwards, backwards and medially from the lateral pelvic wall and converges for insertion into the perineal body, anal canal, anococcygeal raphe, sides of coccyx and lower part of sacrum.

Table 22.1: The muscles of pelvic wall

Muscle	Origin	Insertion	Action	Nerve supply
Piriformis	• Anterior (pelvic) surface of sacrum by three digitations • Gluteal surface of ilium near posterior inferior iliac spine • Capsule of sacroiliac joint	Upper border of greater trochanter of femur.	Lateral rotator of femur.	Direct branches from nerves S1, S2.
Obturator internus	• From pelvic surface of hip bone including the following (Fig. 22.1): – Body, superior ramus, and inferior ramus of pubis. – Ramus and body of ischium. – Pelvic surface of hip bone below the pelvic brim • Obturator membrane.	• Tendon leaves the pelvis through the lesser sciatic foramen and appears in the gluteal region. • It then runs laterally behind the hip joint and inserts into the medial surface of greater trochanter of femur in front of trochanteric fossa (Fig. 22.1).	Lateral rotator of femur	Nerve to obturator internus (L5, S1, S2)

MUSCLES OF PELVIC WALL

The pelvic muscles arise from the inner wall of the bony pelvis (Table 22.1). These are:

- Piriformis
- Obturator internus
- Levator ani
- Coccygeus.

Dissection

The walls of pelvis can be better studied in an isolated sagittal section specimen of the pelvis. Clean the internal iliac artery and trace its branches. After identifying the arterial branches, shift your attention to the nerves. Trace the various branches of the sacral plexus. Finally the muscles may be studied. Piriformis, Levator ani and coccygeus can be cleaned; their attachments and parts should be identified and studied.

Levator Ani Muscle (Fig. 22.1)

Levator ani is a broad muscular sheet attached to the internal surface of true pelvis and forms a large portion of pelvic floor. The levator ani forms a transverse partition called the ***pelvic diaphragm*** across the pelvis. This diaphragm separates the pelvic viscera situated above from structures in the perineum and the ischiorectal fossa below. The pelvic diaphragm is pierced by the rectum, urethra and in the female (additionally) by the vagina (Figs 22.2 and 22.3). Though the muscle is subdivided into named parts depending on the attachments of these parts, the boundaries between each part cannot be clearly distinguished. The individual parts of the levator ani muscle are the ischiococcygeus, iliococcygeus and pubococcygeus.

Ischiococcygeus

This is also called the coccygeus. It is the posterior superior part of the levator ani muscle and is a triangular musculotendinous sheet. The sacrospinous ligament is considered to be a degenerate part of the ischiococcygeus.

- ***Origin:*** Pelvic surface of the tip of ischial spine.
- ***Insertion:*** Base of the muscle is attached to the lateral margins of coccyx and fifth sacral segment.

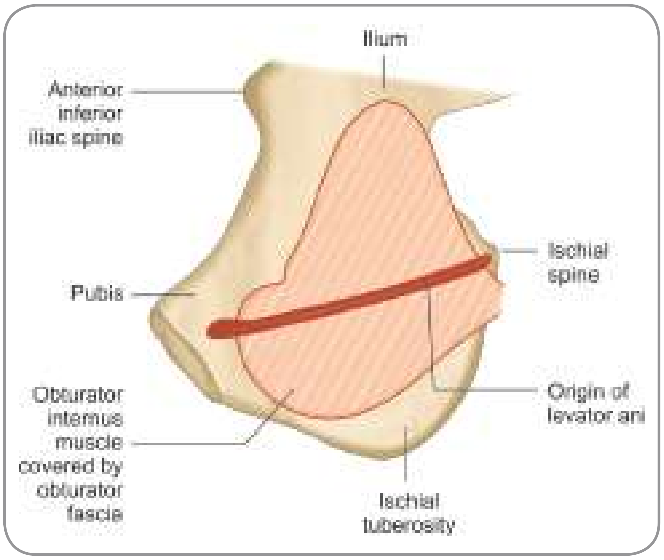


Fig. 22.1: Lower part of hip bone viewed from the pelvic aspect to show the obturator internus and the origin of the levator ani

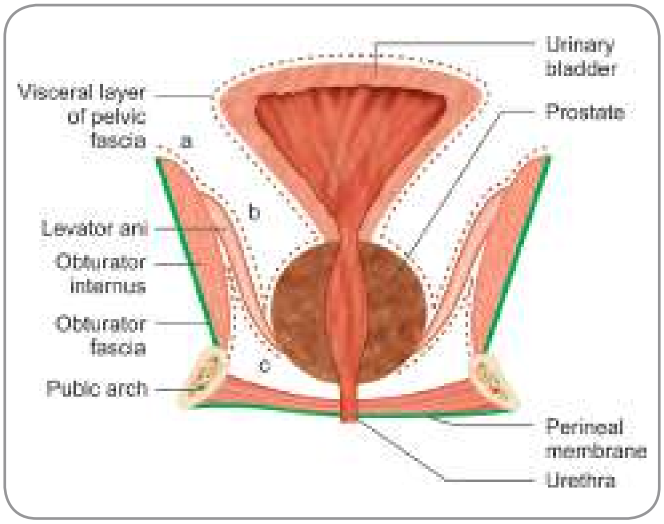


Fig. 22.2: Coronal section through the anterior part of the pelvic diaphragm in the male

Key: **a.** Greater pelvis **b.** Lesser pelvis **c.** Ischioanal fossa

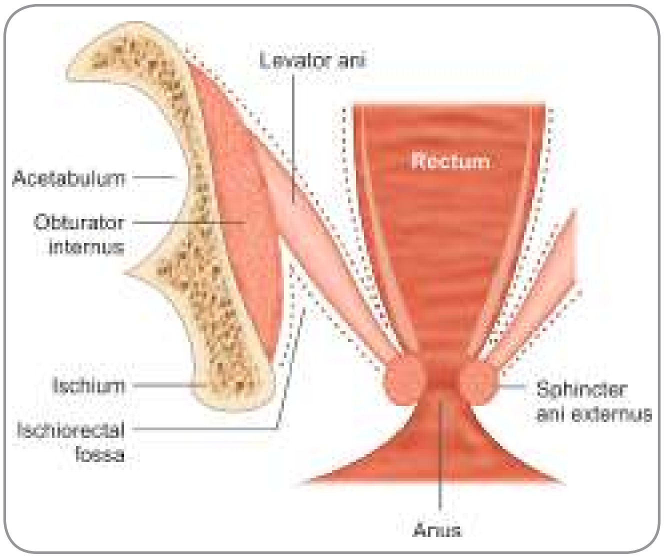


Fig. 22.3: Coronal section through the posterior part of the pelvic diaphragm in the male

Iliococcygeus

This part of the muscle is thin and aponeurotic.

- ***Origin:*** Pelvic surface of the ischial spine below and anterior to the attachment of ischiococcygeus, tendinous arch of levator ani(condensation of obturator fascia) upto the obturator canal.
- ***Insertion:*** Most posterior fibres are attached to the tip of sacrum and coccyx, rest of fibres join with the opposite side to form a raphe. Some fibres may attach to the ano coccygeal ligament, which is present on the inferior surface of the raphe.

Pubococcygeus

- ***Origin:*** Posterior surface of the body of pubis and from anterior part of obturator fascia.
- ***Insertion:*** The most ***medial fibres*** run lateral to the urethra and its sphincter (pubourethralis part). Behind the urethra, the fibres decussate, then run on either side of the prostate in males (puboprostaticus part) or on either side of the vagina in females as a sling (pubovaginalis part) and finally insert into the perineal body in both sexes.

Behind the rectum, some fibres of pubococcygeus form a muscular sling (pubo rectalis part) and insert into the anorectal junction. Some fibres also decussate and blend with the longitudinal rectal muscle coat and the wall of the external anal sphincter (pubo analis part).

- ***Innervation:*** A branch from 4th sacral nerve and sometimes a branch from inferior rectal nerve or from perineal division of pudendal nerve.

Actions

- The levator ani forms the major portion of the pelvic floor and thereby is responsible for expulsion of urine and faeces and for support of pelvic viscera. Contraction of the levator ani along with the abdominal muscles and diaphragm increases the intra abdominal pressure, which helps in expulsion of the abdominal contents.
- Levator ani is also active in the inspiratory phase of quiet respiration like the diaphragm and unlike the abdominal muscles.
- The shape of pelvic floor (mainly contributed to by the levator ani and its attachments) also helps to direct the foetal head into the antero posterior diameter of pelvic outlet.
- The levator ani fixes the perineal body and supports the pelvic viscera.
- During micturition, defaecation or parturition, though the concerned pelvic outlet is open, contraction of levator ani around other openings resists the increased intra abdominal pressure and prevents prolapse through the pelvic floor.
- With respect to the individual parts of levator ani:
  - Pubococcygeus causes lateral compression of the visceral canals passing through the pelvic floor.
  - Puborectalis causes reinforcement of the external anal sphincter and formation of the ano rectal angle.
  - Iliococcygeus and ischiococcygeus assist the puborectalis in the maintenance of anorectal and urinary continence.
  - The coccygeus pulls the coccyx forwards after it has been pushed back during defaecation or parturition.

Clinical Correlation

- The pelvic diaphragm may be greatly stretched during child birth and may be weakened leading to prolapse of uterus.
- When the perineal body is torn during parturition or not properly repaired after injury, contraction of levator ani causes widening of the normal gap in the pelvic floor , resulting in prolapse of uterus.

Development

Development of Pelvic Diaphragm

The sacral and coccygeal myotomes split into the ventrolateral and dorsomedial parts. The dorsomedial parts degenerate early and form the dorsal sacral ligaments. The ventral portions (akin to the flexor musculature elsewhere) form the muscles of the pelvic diaphragm. The medial part of the levator ani is considered a homologue of the ventral vertical muscles (the column of rectus muscles).

FASCIAE OF PELVIC WALL

The pelvic fasciae can be divided into:

- ***Parietal pelvic fascia***, which covers the pelvic muscles;
- ***Visceral pelvic fascia***, which covers the pelvic viscera, nerves and blood vessels.

Parietal Pelvic Fascia

The parietal pelvic fascia consists of the obturator fascia, fascia over piriformis, fascia over levator ani and presacral fascia.

Obturator Fascia

The parietal pelvic fascia covering the obturator internus muscle is called the ***obturator fascia***. Above, it extends between the arcuate line of ilium and the back of pubis and is continuous with the iliac fascia. It invests the obturator canal and behind the obturator canal, it is aponeurotic and gives firm attachment to levator ani, where it is called the ***tendinous arch of levator ani (arcus tendineus musculi levatoris ani)***. Below the attachment for levator ani , the obturator fascia is thin. This part of the fascia forms part of the lateral wall of the ischioanal fossa posteriorly and merges with the fascia of the muscles of the deep perineal space anteriorly.

Fascia Over Piriformis

The fascia over the inner aspect of piriformis is very thin and fuses with the periosteum on the front of sacrum at the margins of the anterior sacral foramina. It separates the internal iliac vessels and their branches from the muscle; but the sacral nerves lie between the muscle and the fascia.

Fascia over Levator Ani

The fascia over levator ani covers both the surfaces of the pelvic diaphragm i.e levator ani.

On the inferior surface, the fascia is thin and forms the medial wall of the ischioanal fossa. Medially, it blends with the fascia over the urethral and the external anal sphincter and laterally it is continuous with the obturator fascia below the tendinous arch of levator ani.

On the superior surface, the fascia is thick. Anteriorly, it is attached to the posterior surface of the body of pubis, extending over the superior ramus and then becomes continuous with the obturator fascia. Posteriorly, it continues over the fascia covering piriformis and the ano coccygeal ligament. Medially, it blends with the visceral pelvic fascia.

Over the superomedial aspect of the upper fascia over levator ani, a thick white band of condensed connective tissue extends from the lower part of the pubic symphysis to the inferior margin of the ischial spine. This band is called the the ***tendinous arch of pelvic fascia (arcus tendineus fasciae pelvis).*** It is also referred to as the ***white line of parietal pelvic fascia*** and is considered to be a remnant of the degenerate tendon of iliococcygeus. It provides attachment for the condensations of visceral pelvic fascia which provide support to the urethra and bladder in males and additionally the vagina in females.

Presacral Fascia

The presacral fascia forms a hammock like structure posteriorly. It extends laterally between the fascia covering the piriformis and levator ani. Inferiorly, it extends upto the anorectal junction and blends with the anococcygeal ligament. Superiorly, it extends upto the origin of the superior hypogastric plexus. The right and left hypogastric nerves and the inferior hypogastric plexus lie over the fascia and the presacral veins lie deeper to it.

Visceral Pelvic Fascia

The visceral pelvic fascia is formed from condensations of connective tissue closely related to the pelvic viscera and the associated neurovascular structures. Laterally, it is derived from the fascia covering the superior surface of levator ani and posteriorly from the fascia covering piriformis. The condensations where all these fasciae meet are collectively called the endo pelvic fascia. The portions of the visceral pelvic fascia adjacent to the pelvic viscera form the paravisceral fascia (on either side and surrounding the concerned viscus) and are called by names related to the specific viscus. Thus, they are the parametrium (around the uterus), paracolpos (around the vagina) etc.

Several condensations of the endopelvic fascia are present in the pelvis; these provide important support to the pelvic viscera and also play a significant role in the maintenance of continence. The periurethral connective tissue condenses to form the pubourethral and urethropelvic ligaments which are attached to the white line of the parietal pelvic fascia. At the cervico-vaginal junction, the endopelvic fascia condenses to form the Mackenrodt's ligament, pubocervical and uterosacral ligaments. Comparatively, there is much less condensation of connective tissue around the rectum.

Clinical Correlation

The pelvic fascia provides support to the pelvic viscera. The presacral fascia serves as a landmark during surgeries. Extension of rectal tumours through the presacral fascia reduces the possibility of curative surgery.

BLOOD VESSELS OF TRUE PELVIS

The blood vessels of the true pelvis constitute the unpaired median sacral artery, the unpaired superior rectal artery and the paired internal iliac arteries, their branches and the corresponding veins.

Median Sacral Artery

The median sacral artery arises from the dorsal aspect of the abdominal aorta immediately above the bifurcation of the latter. It supplies the back of rectum and tissues of the postrectal space. The spinal branches of this artery supply the contents of the spinal canal.

Superior Rectal Artery

The superior rectal artery is the continuation of the inferior mesenteric artery and is the principal artery of the rectum.

Internal Iliac Artery

Each internal iliac artery (right or left) begins as a terminal branch of the common iliac artery, in front of the sacroiliac joint. It runs downwards to reach the upper margin of the greater sciatic foramen. Here, it divides into anterior and posterior trunks. In the foetus, the internal iliac artery is larger than the external iliac artery and is the direct continuation of common iliac artery. It ascends over the anterior abdominal wall and enters the umbilical cord as the umbilical arteries. At birth, once placental circulation ceases, the abdominal portion of the umbilical arteries become the fibrous medial umbilical ligaments and the pelvic portion of the original vessel remains as the internal iliac artery and a part of the superior vesical artery.

Relations of the Artery (Fig. 22.4)

- ***Anterior:*** Pelvic part of ureter in both sexes; in females, it is related to the ovary and fimbriated end of uterine tube and forms the posterior boundary of ovarian fossa.
- ***Posterior:*** (from before backwards) Internal iliac vein, lumbosacral trunk and sacroiliac joint.
- ***Lateral:*** (from above downwards) Medial border of psoas major, external iliac vein and obturator nerve.
- ***Medial:*** Covered by peritoneum, crossed by the terminal part of ileum on the right side and by the sigmoid colon with its mesocolon on the left side.

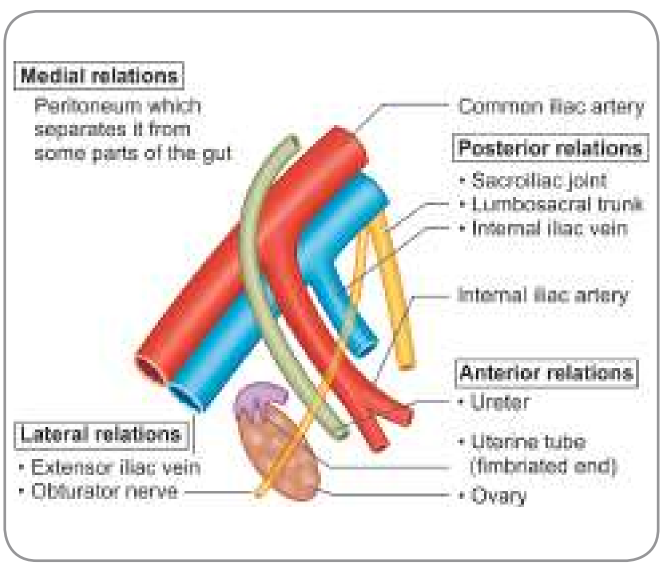


Fig. 22.4: Some relations of the internal iliac artery as seen from the medial side

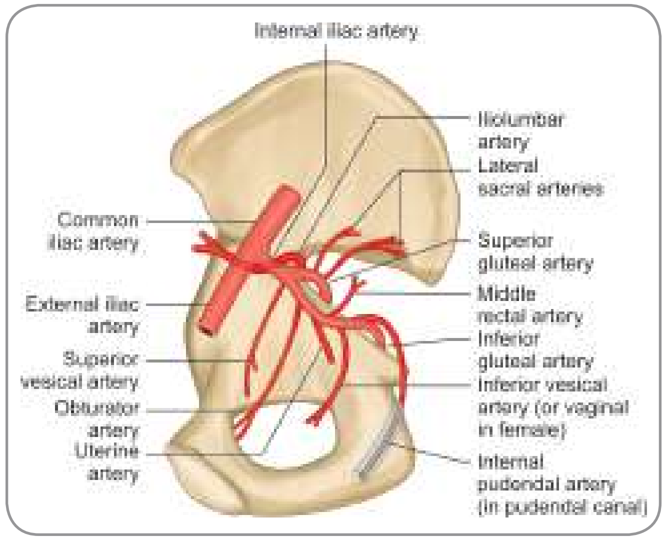


Fig. 22.5: Scheme to show the branches of the internal iliac artery

Branches of Internal Iliac Artery (Fig. 22.5)

As already noted, the internal iliac artery divides into anterior and posterior trunks at the upper margin of the greater sciatic foramen. Further branches arise from these trunks.

Branches Arising from the Anterior Trunk

- Superior vesical artery (Fig. 22.6)
- Inferior vesical artery (Fig. 22.6)
- Middle rectal artery
- Uterine artery
- Obturator artery
- Vaginal artery
- Inferior gluteal artery—terminal branch
- Internal pudendal artery—terminal branch

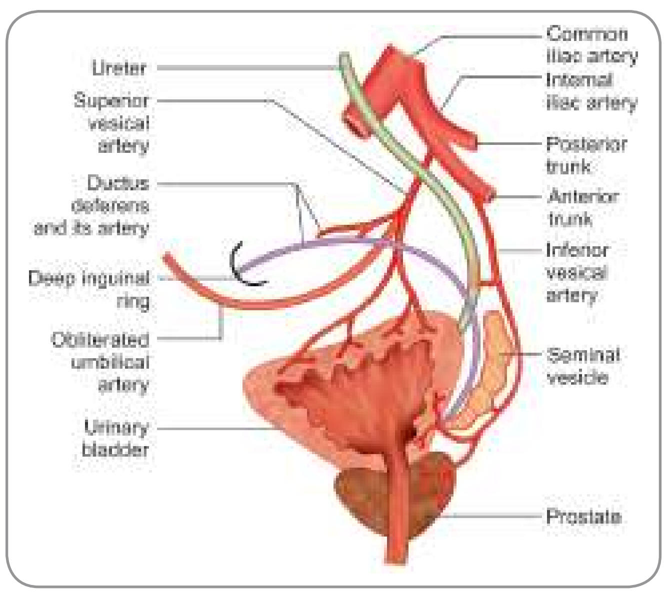


Fig. 22.6: Scheme to show the superior and inferior vesical arteries

Branches of the Anterior Trunk in Detail

- The ***superior vesical artery (Fig. 22.6)*** runs forwards and medially to supply the upper part of the urinary bladder. The artery is crossed by the ductus deferens and gives a branch to it. It also gives a few twigs to the ureter. The stem of the artery represents the proximal part of the umbilical artery of the foetus. It is continuous with the medial umbilical ligament that represents the obliterated part of the umbilical artery.
- The ***inferior vesical artery (Fig. 22.6)*** is present only in the male. It runs forwards and medially to supply the urinary bladder, the prostate, the seminal vesicle and the lower end of the ureter .
- In the female, the inferior vesical artery is replaced by the ***vaginal artery*** that supplies the vagina, the urinary bladder and part of the rectum. The branches anastomose with the branches of the utrerine artery in the median line in front and back of the vagina forming the ***anterior and posterior azygos arteries*** of the vagina.
- The ***middle rectal artery*** runs medially to reach the rectum, where it anastomoses with the superior and inferior rectal arteries. Apart from the rectum, it supplies the bladder,seminal vesicles and the prostate.
- The ***uterine artery (Fig. 22.7)*** is present in the female only and runs medially on the pelvic floor (formed by the levator ani), lateral to the pelvic part of ureter to reach the lateral side of the upper end of the vagina i.e., lateral vaginal fornix. Here , the artery crosses above the ureter from lateral to medial side and then passes upwards along the side of uterus, within the two layers of the broad ligament to reach the junction of the uterus with the uterine tube. It turns laterally below the uterine tube, enters the mesovarium to reach the hilum of the ovary where it anastomoses with the ovarian artery. The uterine artery supplies the uterus, the uterine tube, ovary, urinary bladder, terminal part of ureter and also vagina.
- The ***obturator artery (Figs 22.8 and 22.9)*** runs forwards and downwards on the lateral pelvic wall accompanied by the obturator nerve above and the corresponding vein below. It then leaves the pelvic cavity through the obturator canal and divides into anterior and posterior branches around the margins of obturator foramen. Within the pelvis, the obturator artery gives branches to the urinary bladder, nutrient vessels to the ilium and a pubic branch (Fig. 22.8). The pubic branch runs over the pubis and anastomoses with the pubic branch of the inferior epigastric artery. Sometimes the anastomosis is so large that the obturator

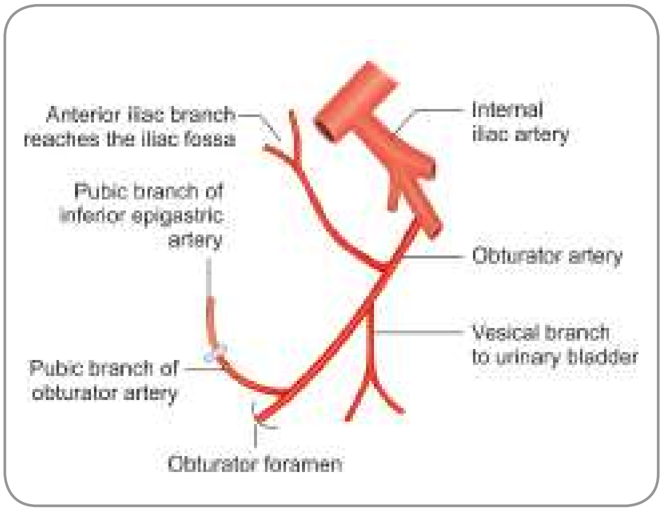


Fig. 22.8: Scheme to show the branches given off by the obturator artery within the pelvis

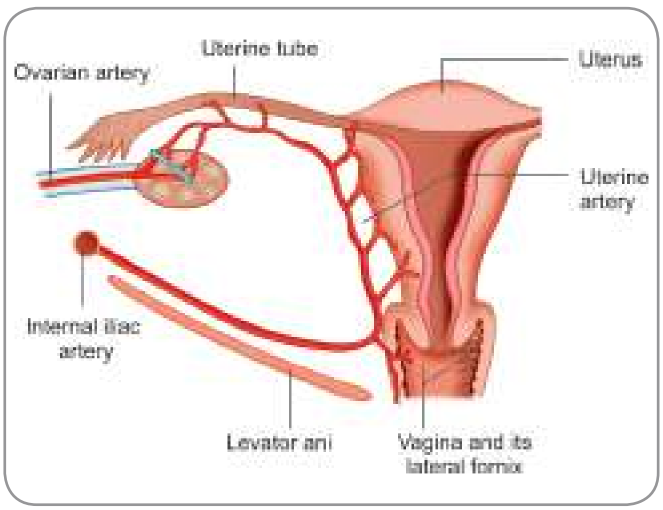


Fig. 22.7: Scheme to show course and branches of the uterine artery

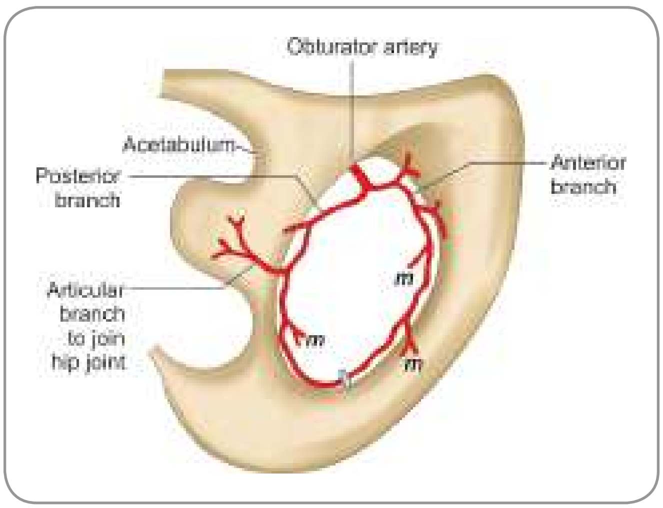


Fig. 22.9: Scheme to show the branches given off by the obturator artery outside the pelvis

Key: m. muscular branch

artery appears to be a branch of the inferior epigastric artery (Fig. 22.8). It is then called the ***abnormal obturator artery***.

The importance of an abnormal obturator artery lies in the fact that it is closely related to the neck of the sac of femoral hernia. The hernia passes through the femoral canal lying medial to the femoral vein. In cases of strangulation of the hernia, the surgeon may cut the lacunar ligament to enlarge the femoral canal. Usually the abnormal obturator artery passes lateral to the femoral canal, in contact with the femoral vein and is in a safe position in the said surgical procedure. However, it may lie along the medial margin of the femoral ring i.e., along the free margin of the lacunar ligament. Such an abnormal position places the artery at risk as it may be cut if an attempt is made to enlarge the femoral ring leading to severe haemorrhage.

- The ***inferior gluteal artery*** is one of the terminal branches of the anterior trunk. It begins within the pelvis anterior to the piriformis, between the first and second sacral nerves. It then leaves the pelvis through the greater sciatic foramen below the piriformis, to enter the gluteal region.
- The ***internal pudendal artery*** is the other terminal branch and leaves the pelvis through the greater sciatic foramen between the piriformis and coccygeus to enter the gluteal region. After a short course in this region, the artery passes through the lesser sciatic foramen, crossing the dorsal surface of the ischial spine in relation to the pudendal nerve. It then runs through the pudendal canal in the lateral wall of the ischiorectal fossa and appears in the deep perineal pouch and divides into two terminal branches, deep artery of penis/clitoris and dorsal artery of penis/clitoris. The branches in the perineum are the inferior rectal artery, perineal branch, artery to the bulb of penis/vestibule,urethral artery and the two terminal branches, the deep and dorsal arteries of penis/clitoris.

Branches Arising from the Posterior Trunk

- Superior gluteal artery
- Iliolumbar artery
- Lateral sacral artery

Branches of Posterior Trunk in Detail

- The ***superior gluteal artery*** is the main continuation of the posterior trunk of the internal iliac artery and is the largest branch of the internal iliac artery. It passes between the lumbosacral trunk and the first sacral nerve and leaves the pelvic cavity by passing through the greater sciatic foramen, above the piriformis muscle to enter the gluteal region.
- The ***iliolumbar artery (Fig. 22.10)*** runs upwards and laterally in front of ala of sacrum between the lumbosacral trunk and obturator nerve and passes deep to the psoas major where it divides into a ***lumbar branch*** that supplies the psoas major and an ***iliac branch*** that supplies the iliacus and ilium.

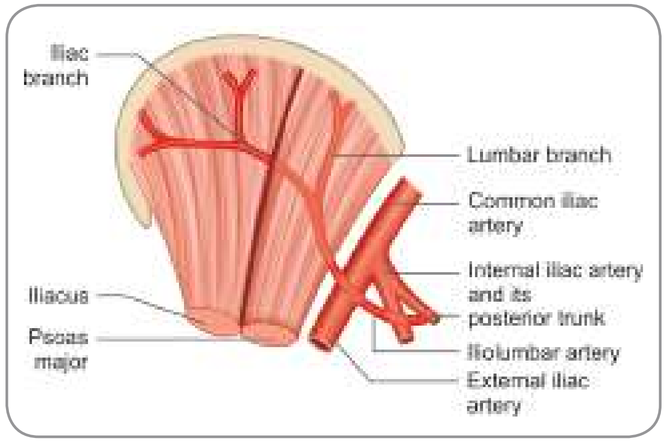


Fig. 22.10: Course and branches of iliolumbar artery

- The ***lateral sacral arteries***, superior and inferior, pass medially and divide into branches that pass through the anterior sacral foramina to supply the sacrum and contents of sacral canal. They then leave through the posterior sacral foramina to supply the skin and muscles dorsal to sacrum.

Added Information

The branches of the internal iliac artery can also be classified in a different way—as the parietal and visceral branches. The parietal branches are obturator artery, inferior gluteal artery, internal pudendal artery of the anterior trunk and all the branches of the posterior trunk, namely superior gluteal artery, ilio-lumbar and lateral sacral arteries.

The visceral branches are superior and inferior vesical arteries,middle rectal, uterine and vaginal arteries (all the branches of anterior trunk).

Clinical Correlation

In uncontrolled post partum haemorrhage, when medical management fails , hysterectomy (surgical removal of uterus) may be indicated. In such cases, the internal iliac artery is ligated to control the haemorrhage as an alternate to hysterectomy to preserve the uterus.

Internal Iliac Veins

Each internal iliac vein is formed by the confluence of several veins that accompany the branches of the internal iliac artery with the exception of the iliolumbar veins, which end in the common iliac veins. The vein begins near the upper part of the greater sciatic foramen and then runs upwards posteromedial to the internal iliac artery. The vein ends by joining the external iliac vein to form the common iliac vein anterior to the sacroiliac joint.

The pelvic organs are drained through a number of venous plexuses which ultimately drain into the internal iliac vein. These plexuses surround the urinary bladder (vesical plexus), the prostate, the uterus, the vagina and the rectum.

The ***prostatic plexus*** of veins receives the deep dorsal vein of the penis. The deep dorsal vein is placed on the dorsum of the penis, in the middle line, deep to the deep fascia, in between the right and left dorsal arteries. The prostatic plexus communicates with the vesical plexus and drains into the internal iliac vein through the veins from the urinary bladder. It also gives origin to the venae comitantes of the internal pudendal artery.

The ***rectal venous plexus*** surrounds the rectum and connects anteriorly with the vesical plexus in males or the uterovaginal plexus in females. It consists of two parts—internal and external venous plexuses which communicate freely. The internal rectal venous plexus lies within the submucosa. It drains mainly into the superior rectal vein which becomes continuous with the inferior mesenteric vein. The external rectal venous plexus lies outside the muscular coat and is drained by all the three veins of the rectum. The lower portion of the external plexus drains into the inferior rectal vein which drains into the internal pudendal vein. The middle portion of the external plexus drains into the middlie rectal vein and thence into the internal iliac vein and the upper portion of the plexus drains into the superior rectal vein which continues as the inferior mesenteric vein.The superior rectal vein is a tributary of the portal venous system, while the middle and inferior rectal veins are part of the systemic circulation. Therefore, the rectal venous plexus is a site of porta-systemic communication.

NERVES OF PELVIS

The nerves of the pelvis can be broadly divided into the ***somatic nerves*** and the ***autonomic nerves***. The somatic nerves are the branches of the lumbosacral trunk, sacral and coccygeal plexuses. The autonomic nerves are the pelvic parts of the sympathetic and parasympathetic nervous systems.

Somatic Nerves

- The ***lumbosacral trunk*** is derived from the fourth and fifth lumbar nerves. It descends into the true pelvis by passing over the ala of the sacrum to join the sacral plexus. The lumbosacral trunk lies just behind the common iliac vessels.
- The ***genitofemoral nerve*** and ***obturator nerve*** are branches of the lumbar plexus which are seen in the pelvis. The genitofemoral nerve emerges from the surface of the psoas major muscle and runs downwards on its anterior surface.
- The ***obturator nerve*** is a branch of the lumbar plexus from the ventral division of the ventral rami of L2, L3, L4 spinal nerves. It runs forwards on the lateral wall of the true pelvis just above the obturator artery and leaves the pelvis through the obturator canal to reach the thigh. In the lateral pelvic wall, the obturator nerve is crossed medially by the internal iliac vessels, ureter, vas deferens in males, round ligament and lateral margin of broad ligament in females.
- The ***sacral plexus*** is formed by the lumbosacral trunk, ventral rami of S1, S2 and S3 , and part of S4. The remainder of S4 joins the coccygeal plexus. It lies against the posterior pelvic wall anterior to piriformis, posterior to the internal iliac vessels and ureter and behind the sigmoid colon on the left side. Altogether twelve named branches arise from the sacral plexus of which five nerves are confined to the pelvis and the remaining seven supply the gluteal region and lower limb. The main continuation of the sacral plexus is the ***sciatic nerve*** that passes out of the pelvis into the gluteal region through the greater sciatic foramen and the other terminal branch of sacral plexus is the ***pudendal nerve***.
- The ***coccygeal plexus*** is formed by the small descending branches of the ventral rami of S4, S5 and Coccygeal nerves. It lies over the pelvic surface of the coccygeus muscle. The plexus gives off the ***anococcygeal nerves,*** which pass through the sacrotuberous ligament to reach the skin overlying the coccyx.
- ***The nerves that are located in the pelvis:***
    - ***Nerve to piriformis:*** It arises from the dorsal branches of the ventral rami of S1 and S2 and supplies the piriformis from the pelvic surface of the muscle.
    - ***Nerve to levator ani and coccygeus:*** It convey fibres from the ventral division of S4 and supplies from the pelvic surface of the muscles.
    - ***Perineal branch of S4 nerve:*** It arises from the ventral division of S4 nerve and pierces the coccygeus and appears in the ischiorectal fossa near the tip of the coccyx to supply the sphincter ani externus and the adjacent skin.
    - ***Pelvic splanchnic nerves:*** They arise from the ventral divisions of S2, S3 and S4 nerves and carry preganglionic parasympathetic motor fibres and viscerosensory fibres to the pelvic viscera.
    - ***Pudendal nerve:*** It is a smaller terminal branch of the sacral plexus and arises from the ventral divisions of S2, S3 and S4 nerves. The nerve passes through the greater sciatic foramen below the piriformis to enter the gluteal region. After a short course in this region, it crosses the dorsal surface of the ischial spine medial to the internal pudendal vessels and nerve to obturator internus and passes through the lesser sciatic foramen to reach the pudendal canal in the lateral wall of the ischiorectal fossa. The nerve is

distributed mainly to the perineum through inferior rectal nerve, and two terminal branches, perineal nerve and dorsal nerve of penis.

Autonomic Nerves

Pelvic Part of Sympathetic Trunk

The pelvic part of the sympathetic trunk bears four or five ***sacral ganglia***. In front of the coccyx, the right and left sympathetic trunks both end in a median ganglion, the ganglion impar. Branches arising from the pelvic part of the sympathetic trunk are distributed mainly to blood vessels of the lower limbs.

Sacral Parasympathetic Outflow

Preganglionic neurons that constitute the sacral parasympathetic outflow are located in segments S2, S3 and S4 of the spinal cord. The nerve fibres pass into corresponding nerves called the ***pelvic splanchnic nerves***. Preganglionic neurons end in plexuses related to various pelvic viscera. Postganglionic neurons are located in these plexuses. Some fibres pass through the hypogastric plexuses to reach parts of the alimentary tract derived from the hindgut.

LYMPHATICS OF PELVIS

Lymph from most of the pelvic viscera drains into the ***internal iliac nodes***. Others reach the ***sacral nodes*** lying in front of the sacrum, the ***external iliac nodes*** and through them to common iliac nodes. Some structures in the perineum drain into ***superficial*** or ***deep inguinal lymph nodes***.

Multiple Choice Questions

1. The continuation of the common iliac artery in the foetus is:
   a. External iliac artery
   b. Internal iliac artery
   c. Median sacral artery
   d. Superior rectal artery

2. The sacrospinous ligament is a degenerated part of:
   a. Ischiococcygeus
   b. Iliococcygeus
   c. Pubococcygeus
   d. Spinococcygeus

3. The parametrium is the paravisceral portion of the:
   a. Parietal pelvic fascia
   b. Visceral pelvic fascia
   c. Presacral fascia
   d. Obturator fascia

4. Which of the following is present only in the male?
   a. Superior vesical artery
   b. Inferior vesical artery
   c. Middle rectal artery
   d. Obturator artery

5. Which of the following is/are branches of coccygeal plexus?
   a. Pudendal nerve
   b. Nerve to coccygeus
   c. Anococcygeal nerves
   d. Perineal nerve

ANSWERS

1. b **2.** a **3.** b **4.** b **5.** c

Chapter 23

Pelvic Viscera—I: Viscera of Digestive System, Urinary System and Male Reproductive System

Frequently Asked Questions

- Discuss the rectum in detail.
- Write notes on: (a) Anal canal, (b) Ligaments of urinary bladder, (c) Ductus deferens.
- Write briefly on: (a) Sphincters of urethra, (b) Prostate, (c) Uterine tubes.
- Discuss the uterus in detail.

In the true pelvis, viscera of gastrointestinal, urinary and reproductive systems are seen. The viscera of the digestive system are the sigmoid colon, rectum and anal canal. In addition, some coils of small intestine are also present in the pelvis. The viscera of the urinary system are the pelvic parts of ureters, urinary bladder and urethra. The main reproductive organs seen in the male pelvis are the pelvic part of ductus deferens, seminal vesicles and prostate gland and in the female pelvis are the uterus, uterine tubes and vagina. In this chapter, we shall deal with the viscera of the digestive system and the urinary system. Since it is not possible to separate the male reproductive organs from the organs of the urinary system, a study of the male reproductive organs is also undertaken along.

PELVIC VISCERA OF THE DIGESTIVE TRACT

As already stated, the viscera of the digestive tract located in the pelvis are the sigmoid colon, rectum and anal canal.

RECTUM

The rectum (Greek.rego=make straight) is the dilated lower part of the large intestine. It is about 12 cm long and lies within the true pelvis. Its upper end is continuous with the sigmoid colon in front of the third sacral vertebra. The lower end of the rectum lies a little below and in front of the tip of the coccyx and becomes continuous with the anal canal. The lower part of the rectum which is wider than the upper part, is called the ***ampulla***. Though the rectum is a part of large intestine, it differs from the rest of the large intestine in that it does not have sacculations and appendices epiploicae.

The taeniae coli (which are the longitudinal muscles) of the sigmoid colon converge to form two bands 5 cm above the rectosigmoid junction and descend over the anterior and posterior walls of the rectum. Subsequently, the two bands fuse to form an encircling layer of longitudinal muscle that invests the entire rectum. At the rectal ampulla, a few muscular fibres called the ***rectourethralis*** pass anteriorly from the anterior longitudinal fibres to the perineal body and a few other fasciculi extend from the posterior longitudinal fibres (on the posterior wall of rectum and anal canal) to the anterior surfaces of the bodies of second and third coccygeal vertebrae as ***rectococcygeus*** muscles.

The circular muscle layer also surrounds the entire rectum and is thickened in the lower part to form the sphincter ani internus muscle.

Curvatures/Flexures of Rectum

The rectum presents both antero-posterior and lateral curves. The ***antero-posterior*** curves are the ***sacral*** and ***perineal*** flexures. The flexure formed by the rectum when it occupies the sacral concavity is called the sacral flexure. The convex curvature formed at the anorectal junction contributed by the puborectal sling, as the rectum bends backwards at the anorectal junction, is called the perineal flexure.

In addition to the antero-posterior curves, ***three lateral curvatures*** are present; two are convex to the right and one to the left. The upper lateral curve is convex to the right at the junction of S3–S4 vertebrae. The middle curve is the most prominent and convex to the left at the sacro

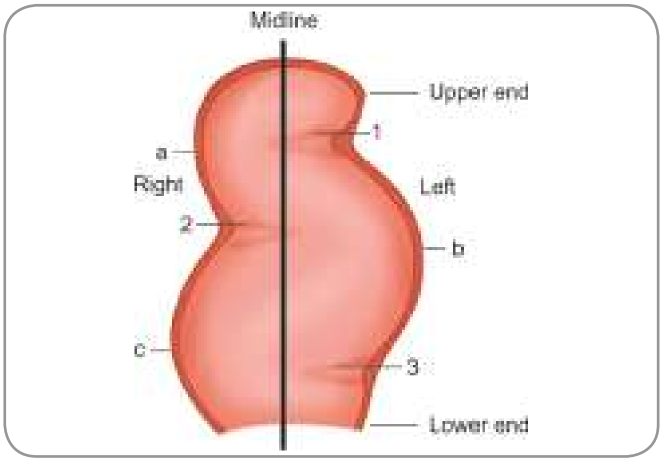


Fig. 23.1: Scheme to show lateral curvatures and folds of the rectum

Key: **a.** Deviates first to right **b.** Then to the left **c.** and again to the right **1**, **2** and **3.** Three folds

coccygeal junction. The lower curve is convex to the right at the tip of the coccyx. The beginning and end of rectum are in the median plane (Fig. 23.1).

Peritoneal Relations

The upper one-third of the rectum is covered by peritoneum both in front and on the sides. The middle one-third is covered by peritoneum only in front and the lower one-third is not covered by peritoneum. In males, the peritoneum is reflected from the front of the rectum to the urinary bladder forming the ***rectovesical pouch***. In females, the peritoneum passes from the front of the rectum to the posterior wall of the vagina forming a pouch called the ***rectouterine pouch*** (***or pouch of Douglas or cavum Douglasi or sometimes rectovaginouterine pouch,*** named after the 17th–18th Scottish anatomist in London, James Douglas), though it is actually rectovaginal. The level of reflection is higher in the males, the bottom of the rectovesical pouch being 7.5 cm from the anus than that of the females in whom, the rectovaginal pouch is about 5 cm from the anus.

Various parts of pararectal pelvic fascia condense to form ligaments in certain sites. Though they are considered to be mechanical supports for rectum, they actually do not provide adequate support. However, they have to be identified and divided for mobilisation of rectum during surgeries. An avascular condensation extending between the anterior surface of the lower part of the sacrum and the posterior aspect of the anorectal junction is called ***Fascia of Waldeyer***. The fascia around the middle rectal artery from the posterolateral wall of pelvis at the level of S3 vertebra to the rectum on each side is called the ***lateral ligament of rectum***. Anteriorly, in males, the fascia extending between the rectum and the seminal vesicles and prostate in males is called the ***rectovesical fascia***; in females, the fascia extending between the rectum and the uterus is called the ***rectouterine fascia***.

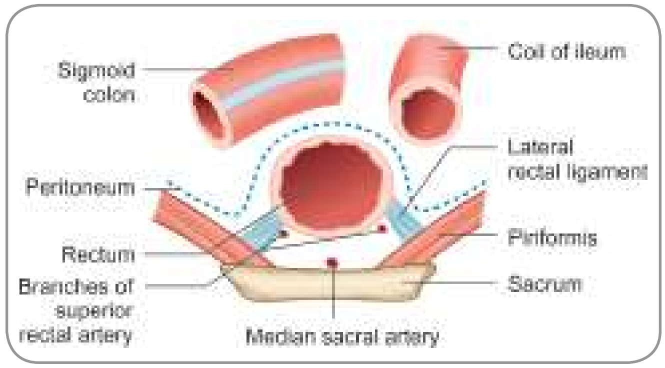


Fig. 23.2: Transverse section through upper one-third of rectum to show some relations

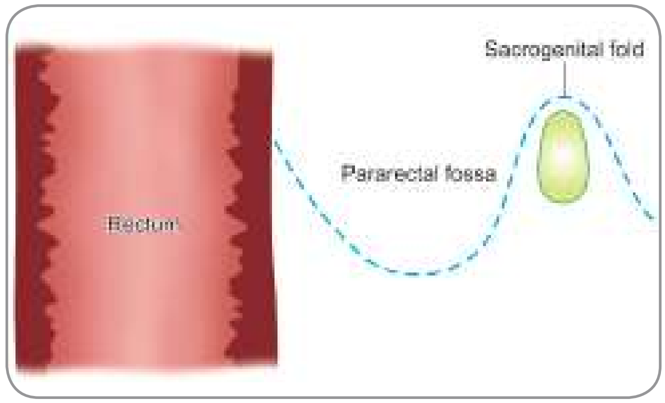


Fig. 23.3: Schematic coronal section through the rectum to show the pararectal fossa

Relations (Fig. 23.2)

Laterally

- The upper part of the rectum is related to the pararectal fossa (Fig. 23.3) of the peritoneum with its contents, sigmoid colon and lower part of ileum.
- Below the peritoneal reflection, the pelvic sympathetic plexuses, coccygei and levator ani muscles and branches of superior rectal vessels constitute the lateral relations.

Posteriorly

- In the median plane, the rectum is related to the lower three sacral vertebrae, the coccyx, the median sacral vessels, the ganglion impar and branches of superior rectal vessels.
- On each side of the midline, it is related to the piriformis, coccygeus and the levator ani muscles, sympathetic trunk, lower three sacral and coccygeal nerves and lower lateral sacral vessels.

Anteriorly

- In the male, the rectum is related to the urinary bladder, the seminal vesicles, the ductus deferentia and the lower ends of the ureters and the prostate (Fig. 23.4).

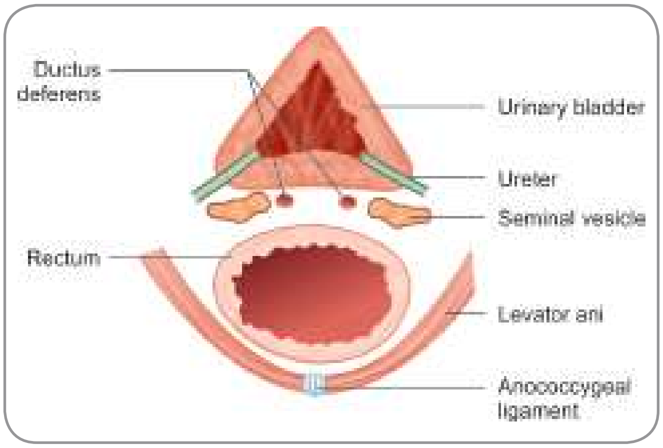


Fig. 23.4: Transverse section through lower part of rectum in the male

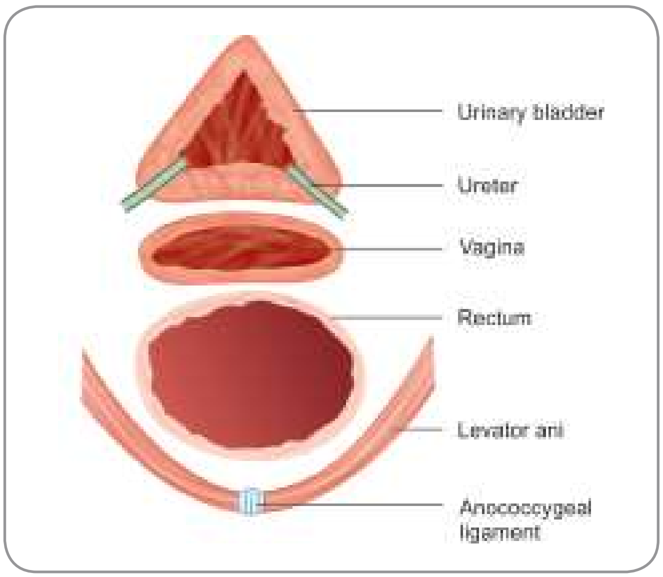


Fig. 23.5: Transverse section through lower part of rectum in the female

- In the female, the rectum is related anteriorly to the vagina and the lower part of the uterus (Fig. 23.5).

In both sexes, the upper two-thirds of rectum may be related anteriorly to the sigmoid colon and/or coils of ileum if these viscera lie in the pelvis (because of its mobility, the loop of sigmoid colon may lie in the lesser pelvis in such a way that it overlaps the rectum).

Interior

In the interior of the rectum, two types of mucous folds are seen—the longitudinal folds and the transverse/horizontal folds.

1. The ***longitudinal folds*** are present in the lower part of the rectum and disappear with distension.
2. The ***transverse folds*** are permanent mucous folds and are also known as ***Houston's valves*** (named after the 19th century Dublin physician John Houston, also called the plicae recti, rectal valves and Kohlrausch's valves). They are semilunar in shape and are situated along the concavities of the lateral curvatures of the rectum. Majority of the folds consist of the mucous membrane and circular muscle coat. Some of the folds contain, in addition, the longitudinal muscle coat. The function of the valves is to support the faeces. Commonly three to four folds are present.
   - The ***upper valve*** is present near the commencement of the rectum, and may be on the left or right side.
   - The ***middle valve*** is situated just above the ampulla and projects from the anterior and right walls of the rectum just below the level at which the peritoneum is reflected from the anterior surface of the rectum. It is the largest and the most constant of all the valves. Sometimes, this valve encircles the rectum, in which case, it is called the ***Nelaton's sphincter*** or Nelaton's fibres (named after the 19th century French surgeon Auguste Nelaton).
   - The ***lowest valve*** lies on the left side about 2.5 cm below the middle valve. Sometimes another valve may be present on the left side, about 2.5 cm above the middle fold.

The middle valve divides the interior of rectum into upper and lower chambers which are different in development and functions. The upper chamber develops from the pre-allantoic part of the hind gut and the lower chamber from the post-allantoic part of cloaca. Functionally, the upper chamber may contain faeces without initiation of defaecation, whereas presence of faeces in the lower chamber initiates the reflex for defaecation spontaneously.

Arterial Supply

The principal arterial supply to the upper two-thirds of rectum is the superior rectal artery. A pair of middle rectal arteries supplies the middle third and inferior rectal arteries supply the distal third. The median sacral artery which is the terminal midline branch of aorta contributes a small portion.

- ***Superior rectal artery*** is the principal continuation of the inferior mesenteric artery and divides into right and left branches at the rectosigmoid junction. Branches of both sides subdivide into smaller terminal branches which pierce the rectal wall and form a plexus in the submucous coat of rectum where they anastomose with the ascending branches of the inferior rectal artery.
- ***Middle rectal artery*** is a branch of the anterior division of internal iliac artery, passes through the lateral ligaments of rectum and supply the mid and lower rectum, but form poor anastomosis with the superior and inferior rectal arteries.

- ***Inferior rectal artery*** is the terminal branch of internal pudendal artery (which is a branch of internal iliac artery) and passes through the ischioanal fossa. It supplies the sphincter ani muscles, perianal skin and the ascending branches anastomose with the branches of superior rectal artery.

Venous Drainage

Rectal veins are arranged in a plexus known as ***annulus haemorrhoidalis*** in the lower part of the rectum and anal canal. The ***rectal venous plexus*** surrounds the rectum and connects anteriorly with the vesical plexus in males or the uterovaginal plexus in females. It consists of two parts—internal and external venous plexuses which communicate freely.

1. The ***internal rectal venous plexus*** lies within the submucosa. It drains mainly into the superior rectal vein which becomes continuous with the inferior mesenteric vein.
2. The ***external rectal venous plexus*** lies outside the muscular coat and is drained by all the three veins of the rectum. The lower portion of the external plexus drains into the inferior rectal vein which drains into the internal pudendal vein. The middle portion of the external plexus drains into the middle rectal vein and thence into the internal iliac vein and the upper portion of the plexus drains into the superior rectal vein which continues as the inferior mesenteric vein.

The superior rectal vein is a tributary of the portal venous system, while the middle and inferior rectal veins are part of the systemic circulation. Hence, the rectal venous plexus is one of the site of portasystemic communications.

The tributaries of superior rectal vein ascend as six vessels within the submucosa and pierce the rectal wall about 7.5 cm above the anus. All of them unite to form a single superior rectal vein which continues as the inferior mesenteric vein and finally drains into the splenic vein.

Lymphatic Drainage

The upper part of the rectum drains into the inferior mesenteric nodes through lymph vessels passing along with the superior rectal artery and inferior mesenteric artery. The lower part of the rectum and the upper part of the anal canal drain into the internal iliac nodes through lymph vessels running along with the middle rectal artery.

Innervation

The innervation of the rectum is by both sympathetic and parasympathetic nerves.

- The sympathetic supply is from L1 and L2 spinal segments via lumbar splanchnic nerves through inferior mesenteric plexuses and sacral splanchnic nerves through superior and inferior hypogastric plexuses. They are inhibitory to rectal muscle wall.
- The parasympathetic supply is mediated via pelvic splanchnic nerves through superior and inferior hypogastric plexuses. They are motor to rectal musculature causing relaxation of the internal anal sphincter and secretomotor to colorectal glands. Afferent impulses mediating sensation of distension is carried through parasympathetic nerves, whereas pain impulses are carried by afferents of both sympathetic and parasympathetic nerves.

Histology

Rectum

From outside inwards, rectum presents four layers—serous, muscular, submucous and mucous layers.

1. ***Serous layer:*** It is derived from the peritoneum and covers the rectum partly as discussed above.
2. ***Muscular layer:*** It comprises the outer longitudinal and inner circular layers of smooth muscles.
3. ***Submucous layer:*** It consists of loose areolar tissue and contains plexuses of blood vessels, lymphatics and nerves.
4. ***Mucous layer:*** As in other parts of gastrointestinal tract (GIT), it comprises the muscularis mucosae, lamina propria and surface epithelium from outside inwards (towards lumen). The surface is lined by simple columnar epithelium, goblet cells and crypts of Lieberkuhn extending into the lamina propria.

Added Information

The rectum is usually described as a retroperitoneal organ. However, fascial tissue derived from the embryological hindgut surrounds the rectum till the level of the levator ani muscle. This tissue that lodges the superior rectal vessels with their branches and tributaries, the lymph nodes and lymphatics which lie along the superior rectal artery, twigs of the inferior mesenteric plexus and some adipose tissue is called the mesorectum. The mesorectum is surrounded by a distinct layer derived from the visceral peritoneum and is called the mesorectal fascia or the visceral fascia of mesorectum. It completely encircles the rectum and the mesorectum and blends anteriorly, in males with the rectovesical fascia of Denonvillier and in females, with the rectovaginal septum. Laterally it is separated from the walls of pelvis by loose areolar tissue. Posteriorly, it lies in front of the presacral fascia. The retrorectal space is behind the mesorectal fascia. Superiorly, the mesorectal fascia blends with connective tissue around the sigmoid colon.

Clinical Correlation

Rectal Examination

Considerable information about the structures surrounding the rectum and anal canal can be obtained, in the living, by palpation with a finger inserted through the anus. This is referred to as rectal examination. The procedure is often referred to by medical personnel as "PR" which is an abbreviation for the term 'per rectum'. The structures which can be felt through the anterior wall of the rectum and anal canal in the male are (from below upwards):

- The bulb of the penis and membranous urethra
- The prostate
- The seminal vesicles
- The base of the urinary bladder.

In the female, the main structures in front of the rectum and anal canal are the vagina and uterus, but as these are directly accessible for examination through the vagina, a rectal examination is needed only when, for some reason, a vaginal examination is not desirable. Posteriorly, in both males and females, the coccyx and the lower part of the sacrum can be felt; and laterally, the ischial spine and ischial tuberosity can be palpated. In addition, an experienced surgeon can recognise abnormalities in the surrounding viscera (ovary, uterine tube, ureters, a pelvic appendix) such as inflammation or enlargement. Enlarged internal iliac lymph nodes, abnormalities in the rectovesical/rectouterine pouches, ischioanal fossae can also be detected.

Proctoscopy and Sigmoidoscopy

Examination of the interior of the anal canal and rectum is called ***proctoscopy*** and the instrument used is called the proctoscope. However, it may not be possible to visualise the upper part of the rectum with a proctoscope for which a sigmoidoscope can be used. While passing a sigmoidoscope or a proctoscope into the rectum, the presence of curvatures of the rectum and the presence of transverse folds (valves) have to be remembered and care to be taken to avoid injury.

Prolapse of Rectum

The rectum and other pelvic viscera are supported by the pelvic diaphragm. Damage during parturition or improper repair following injury can cause weakening of the pelvic diaphragm resulting in ***prolapse*** of the rectum out of the anus. Prolapse may be ***partial***, in which case the protrusion consists only of mucosa or ***complete*** where all layers of the rectal wall are present. Weakening of muscles in old age can also be a predisposing factor for prolapse.

Carcinoma

The rectum is commonly affected by carcinoma. Spread of a rectal carcinoma is usually slow but it can ultimately invade the surrounding structures including the prostate, the seminal vesicles and urinary bladder, the uterus and vagina, the ureters and the sacral plexus.

ANAL CANAL

The anal canal (Latin.anus=lower opening) is the lowest part of the alimentary canal. It is continuous, above, with the lower end of the rectum about 2–3 cm in front and slightly below the tip of the coccyx and below, it opens to the exterior at the ***anus***. The anal canal is about 4 cm in length. It is distinctly narrower than the rectum and is directed downwards and backwards. The anorectal junction lies at the level of the pelvic diaphragm formed by the levator ani muscles. The rectum lies above the pelvic diaphragm in the true pelvis, whereas the anal canal lies below the diaphragm in the perineum.

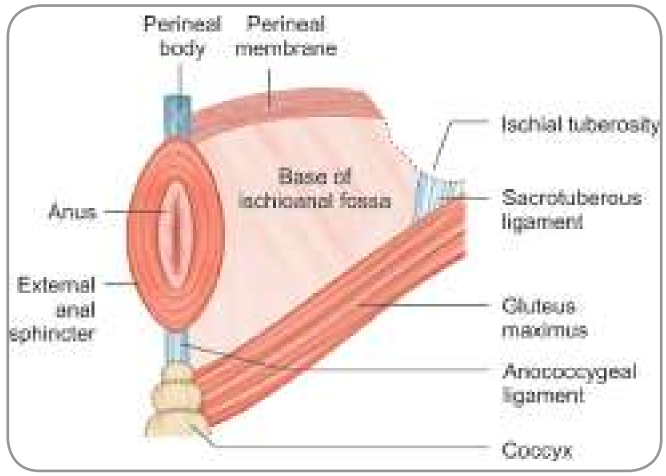


Fig. 23.6: Anal triangle seen after removing overlying skin, to show some relations of the anal canal

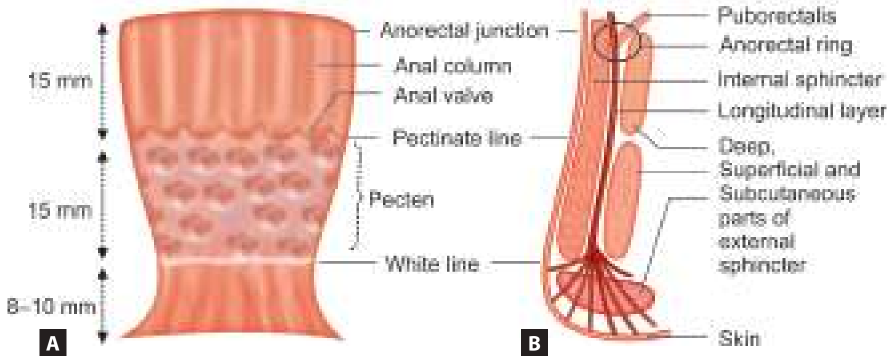
Relations of Anal Canal (Fig. 23.6)

The lower aperture of the anal canal (or anus) is in the form of an anteroposterior slit, the right and left walls being in apposition. The position is the same in the interior of the anal canal also. ***Posteriorly***, the anal canal is separated from the coccyx by a mass of fibromuscular tissue called the ***anococcygeal ligament***. ***Anteriorly***, the ***perineal body*** is present. A number of muscles of the perineum gain attachment to this body and make it a region of importance for maintaining the integrity of the pelvic floor. The perineal body separates the anal canal from the membranous urethra and the bulb of the penis in the male; and from the vagina in the female. ***Laterally***, the anal canal is related on either side to the ***ischioanal fossae***.

Interior

The interior of the anal canal is divided by the pectinate line and Hilton's white line into three zones—upper, intermediate and lower (Fig. 23.7A).

1. ***Upper zone:*** The upper zone is about 1.5 cm in length and limited by the pectinate line below. It is lined by mucous membrane with simple columnar epithelium. The internal venous plexus lies outside the mucous membrane. The mucous membrane shows six to ten longitudinal folds called the ***anal columns*** (***Columns of Morgagni;*** named after 17th–18th century Italian



Figs 23.7A and B: Schemes to show **A.** Some landmarks in the anal canal **B.** The anal musculature

anatomist and pathologist Giovanni Morgagni). Each column is formed by the reduplication of mucous membrane containing radicles of superior rectal vessels. The lower ends of the anal columns are united to each other by short transverse folds of mucous membrane. These folds are called the ***anal valves*** (***the Valves of Morgagni or the Valves of Ball;*** Sir Charles Ball was a 19th century Dublin surgeon***)***.The upper surface of the anal valve is lined by simple columnar epithelium and its lower surface by the stratified squamous epithelium of the intermediate zone. The anal valves together form a transverse line that runs all around the anal canal called the ***pectinate line (or the dentate line; Greek.pecten=comb like)***. Sometimes, epithelial processes project from the anal valves; these are the ***anal papillae*** and are remnants of the anal membrane. Above each anal valve is a depression in the mucosa; this is the ***anal sinus***. The floors of the anal sinuses receive the ducts of the ***anal glands*** which may extend into the submucosa and sometimes into the muscle layer. The openings of the glands on the anal mucosa are referred to as ***anal crypts***.

2. ***Intermediate zone:*** The intermediate zone is also 1.5 cm and extends between the pectinate line and Hilton's line. It is lined by mucous membrane with non-keratinised stratified squamous epithelium without sweat or sebaceous glands. The mucosa has a bluish appearance because of a dense venous plexus that lies between it and the muscle coat. The lining epithelium is adherent to the underlying structure, therefore, the mucosa is less mobile than in the upper part of the anal canal. The intermediate zone is referred to as the ***pecten.*** It is richly supplied by somatic spinal nerves
3. ***Lower zone:*** The lower limit of the pecten often has a whitish appearance because of which it is referred to as the ***white line of Hilton*** (named after the 19th century English surgeon John Hilton). It is the colour contrast between the bluish pink area above and darker skin below which makes it discernible as white line. In some white races, it may not be perceived as a separate line. This zone is about 0.8 to 1.0 cm long. It differs from the upper and middle parts in that it is not lined by mucous membrane, but by true skin in which sebaceous and sweat glands are present. A number of radiating skin folds converge upwards formed by the corrugator cutis ani muscle.

From an embryological point of view, the part of the anal canal above the pectinate line is derived from the cloaca, and its lining epithelium is of endodermal origin. In contrast, the part below the line is derived from a surface depression called the proctodaeum, and its lining epithelium is ectodermal. In early foetal life, the two parts are separated by the anal membrane which subsequently disappears.

The two parts are different in their blood supply, innervations and lymphatic drainage. The upper area is supplied by the ***superior rectal artery*** and drained by the ***portal venous system*** via the superior rectal vein. Its lymphatics drain into the ***internal iliac lymph nodes***. It is innervated by the ***autonomic plexuses***, making it ***insensitive*** to modalities of cutaneous sensation.

In contrast, the lower area is supplied by the ***inferior rectal artery***, drains into the ***systemic veins*** via the inferior rectal vein. Its lymphatics reach the ***superficial inguinal lymph nodes***. It is innervated by the ***somatic nerves***, via the inferior rectal nerve, thereby making it ***sensitive*** to cutaneous sensations.

Added Information

The junction between the columnar and squamous epithelia (the junction between the upper and intermediate zones) is called the anal transition zone (ATZ). It should not be confused with the dentate line and should not be equated to the latter. The transition zone can be best defined as an area of variable height present in the upper part of the intermediate zone where islands of squamous epithelium insinuate into pockets of columnar epithelium. Sensory nerve endings are found in the submucosa of the transition zone. These endings also include thermoreceptors. The nerve endings and receptors are part of the mechanism to detect and identify contents of the lower rectum so that the upper anal canal would relax to allow the contents to move to the anal canal.

Anal Musculature (Fig. 23.7B)

The anal canal is surrounded by two sets of sphincters, namely the internal anal sphincter (sphincter ani internus) and the external anal sphincter (sphincter ani externus). The ***internal anal sphincter*** is formed by the thickening of the circular muscle coat of the rectum. It is therefore made up of smooth muscle and is involuntary. It extends from the upper end of the anal canal up to the white line of Hilton. The middle of the internal anal sphincter corresponds to the pectinate line. Internally the internal sphincter is separated from the mucous membrane by an internal venous plexus present within the sub mucosa and externally it is separated from the external sphincter muscle by a conjoint sheath derived from the levator ani and longitudinal muscle of rectum. It is supplied by sympathetic nerves from superior hypogastric plexus and parasympathetic nerves from the pelvic splanchnic nerves.

The ***external anal sphincter*** is made up of striated muscle and is voluntary. It is subdivided into three parts, namely subcutaneous, superficial and deep parts.

The ***subcutaneous part (pars subcutanea)*** lies below the level of the white line, i.e., inferior to the level of the internal anal sphincter. It is separated from perineal skin by the external venous plexus. When a finger is placed in the anal canal, a distinct ***intersphincteric groove*** which represents the Hilton's line can be palpated between the lower end of the internal sphincter and the upper margin of the subcutaneous external sphincter.

The ***superficial part*** (pars superficialis) of the external anal sphincter lies external to the lower part of the internal sphincter between the levels of the pectinate line and the white line. The fibres of this part are attached posteriorly to the coccyx and anococcygeal raphe and anteriorly to the perineal body.

The ***deep part*** (pars profunda) of the external anal sphincter lies external to the upper half of the internal sphincter above the level of the pectinate line. Most of its fibres run circularly around the anal canal, but some of them become continuous anteriorly with the perineal body where it is continuous with the opposite superficial transverse perinei muscle and posteriorly with the anococcygeal ligament.

The external anal sphincter is supplied by the inferior rectal branch of pudendal nerve and the perineal branch of fourth sacral nerve.

Anorectal Ring

The anorectal junction is closely related to the puborectalis part of the levator ani muscle. The fibres of the puborectalis form a sling (Fig. 23.8) that keeps the anorectal junction pulled forwards, thus maintaining the angle between the rectum and the anal canal. The fibres of the puborectalis

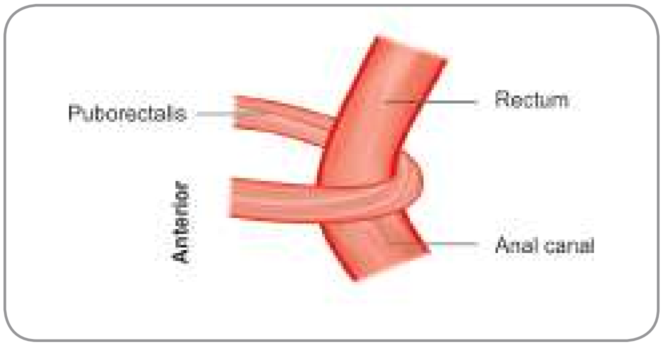


Fig. 23.8: The puborectalis sling

mingle intimately with the ***upper part of the internal anal sphincter***, and with the ***deep part of the external sphincter*** to form a prominent ring of muscle around the anorectal junction. This ring, which can be palpated by a finger placed in the anal canal, is called the ***anorectal ring***. The integrity of this ring is of great functional importance as damage to it results in incontinence of faeces.

Some fibres of the puborectalis also merge with the longitudinal muscle at the lower end of the rectum. Together these fibres descend in the wall of the anal canal between the internal sphincter and the deep and superficial parts of the external sphincter. These longitudinal fibres are intermingled with numerous elastic fibres which become more and more numerous as the bundles descend, so that near the lower end of the internal sphincter, the fibres in the longitudinal layer are almost entirely elastic. These fibres fan out into small bundles which penetrate through the subcutaneous part of the external sphincter to gain attachment to the skin surrounding the anus; these bundles together form the corrugator cutis ani muscle and are responsible for the presence of corrugations in this part of the skin. Some bundles of these elastic fibres pass through the interval between the lower end of the internal sphincter and the upper edge of the subcutaneous external sphincter to reach the skin lining the anal canal thereby forming the intersphincteric groove.

Arterial Supply

The arterial supply is similar to that of the rectum. The mucous membrane of the anal canal up to the anal valves is supplied by the superior rectal artery. The inferior rectal artery supplies the anal sphincters and the entire thickness of the anal canal below the anal valves. In addition, the median sacral artery gives branches to the posterior part of the anorectal junction and the anal canal.

Venous Drainage

The venous drainage is also similar to that of the rectum. The mucous membrane of the anal canal up to the anal valves is drained by the internal venous plexus and the area below the anal valves is drained by the external venous plexus.

Lymphatic Drainage

The upper part of the anal canal drains into the internal iliac nodes as that of the lower part of the rectum. The lower part of the anal canal drains into the superficial inguinal nodes.

Innervation

The nerve supply of the upper part of the anal canal is through autonomic nerves as that of rectum. The internal anal sphincter is also supplied by these nerves. The external anal sphincter is supplied by the somatic nerves, inferior rectal branch of the pudendal nerve and by the perineal branch of the fourth sacral nerve. The region supplied by the inferior rectal nerve is much more sensitive to pain than the region supplied by autonomic nerves.

Clinical Correlation

Haemorrhoids (or Piles)

The term haemorrhoids is used to describe swellings in the anal canal produced by dilated veins. Haemorrhoids may be internal or external.

Anatomical basis for Causation of Haemorrhoids

The submucous connective tissue at the anorectal junction is very loose and the radicles of the superior rectal vein lie unsupported in this tissue. As the veins pierce the muscle coat, they are compressed during muscular contraction in defecation. This increases the pressure within them. As there are no valves in the superior rectal or inferior mesenteric veins, the tributaries of these veins in the anal columns bear the pressure of the entire column of blood right up to the portal vein. Hence, haemorrhoids are more commonly seen in persons who have to stand for long periods or with increased portal hypertension.

Other Causes of Haemorrhoids

Apart from anatomical factors, hereditary factors have also been implicated in the causation of haemorrhoids as it has been observed that persons who have haemorrhoids also frequently have varicose veins, suggesting the possibility of some inherent weakness in the walls of veins. In some cases, haemorrhoids can be caused by pressure on veins or blockage of veins caused by a rectal carcinoma. During pregnancy, haemorrhoids may form because of pressure of the enlarged uterus on the superior rectal vein.

Clinical Features of Haemorrhoids

The most important clinical feature of piles is painless bleeding during passage of stools. Surgically, haemorrhoids are classified as follows—

First degree when the piles do not project out of the anus at anytime.
Second degree when they prolapse out of the anus during defecation, but get reduced by themselves.
Third degree when reduction is not spontaneous after prolapse.

Haemorrhoids cause discomfort when they become large or prolapsed. Discomfort becomes much more severe when there is thrombosis or when the haemorrhoid gets infected or ulcerated. A prolapsed haemorrhoid may get gripped by the external anal sphincter leading to strangulation.

Types

External haemorrhoids: In contrast to internal haemorrhoids, external haemorrhoids are formed by dilatation of tributaries of the inferior rectal veins. They are placed below the anal valves and are covered by skin. They are highly painful. Some haemorrhoids may extend partly under mucosa and partly under skin (***interno-external haemorrhoids***). Rupture of a small tributary of the inferior rectal vein can give rise to a ***perianal haematoma***.

Internal or true haemorrhoids: Internal or true haemorrhoids are located in the part of the anal canal lined by mucosa. They are painless and are located in relation to anal columns above the level of anal valves, and are formed by dilatation of radicles of the superior rectal vein within the anal column. The tributaries located in the left lateral, right posterior, and right anterior positions are largest and the first to enlarge. These enlargements are called ***primary piles***. When the anal canal is viewed with the patient lying supine with the thighs raised (lithotomy position) the position of primary piles is often described with reference to a clock. They are said to be located at the 3 o'clock, 7 o'clock and 11 o'clock positions. Secondary piles may form later at other positions.

Infections in Anorectal Region

The anal canal is a frequent site of infection as it is in constant contact with faecal material. The small glands opening into the anal sinuses are often foci of infection which can lead to the formation of ***abscesses***. In the absence of timely treatment, the abscesses may burst either into the anal canal or rectum or may open to the outside over the skin of the perineum forming sinuses. Sometimes, an abscess may open in both directions leading to the formation of a ***fistula,*** which is a narrow inflamed tract of communication between the lumen of the anal canal and outside.

Perianal abscesses may be seen in the following positions:

- ***Submucous,*** under the mucosa of the anal canal,
- ***Subcutaneous,*** under perianal skin,
- ***Ischioanal,*** in the ischioanal fossa and
- ***Pelvirectal,*** in the space lateral to the rectum just above the levator ani.

contd…

Clinical Correlation *contd...*

Anal Fistulae may present as follows:

- A fistula lying above the level of the anorectal ring is a ***high level*** anal fistula.
- Any fistula lying below the anorectal ring is a low level fistula. The track of such a fistula may lie between the various parts of the external anal sphincter like between the deep and superficial parts of the external anal sphincter, between the superficial and subcutaneous sphincters or superficial to the subcutaneous sphincter.
- Excision of the track of the fistula is the treatment for it. During excision of a high level fistula, division of the anorectal ring is done which has to be repaired correctly to ensure that division of the ring does not result in anal incontinence.

Anal Fissure

Passage of hard faecal mass can produce a tear in the anal valve. The tear usually extends to the anus constituting an anal fissure and is a very painful condition. Fissures tend to occur most commonly in the midline either anteriorly or posteriorly, probably as these sites are least supported by the external sphincter. A ***sentinel pile*** is a tag formed by the ruptured anal valve.

Other conditions affecting the anal canal

- In some newborn infants, the anal canal does not open to the outside. This condition is called ***imperforate anus***.
- A congenital ***stricture*** may develop in the region of the pectineal line. Strictures may also be acquired.
- The anal canal can be the site of a ***carcinoma***.

PELVIC VISCERA OF THE URINARY TRACT

URETERS

The pelvic part of the ureter (Greek.oureter=urinary canal) continues from the abdominal part of the ureter at the level of brim of the pelvis. About half of the total length of the ureter lies within the true pelvis. At the brim of the pelvis, the ureter crosses the upper end of the external iliac vessels and comes to lie on the lateral wall of the pelvis. It then descends posterolaterally on the lateral pelvic wall along the anterior border of the greater sciatic notch to reach the ischial spine. Opposite the ischial spine, it turns medially and forwards to reach the posterolateral part of the urinary bladder. The terminal part of the ureter passes obliquely through the thickness of the wall of the urinary bladder to open into its posterior wall. The openings of the right and left ureter lie at the lateral angles of a triangular area on the posterior wall of the urinary bladder called the ***trigone*** (Fig. 23.9)

The point of termination of the ureter corresponds, on the surface, to the pubic tubercle of its side.

The distal 2–3 cm of each ureter is surrounded by incomplete smooth muscle forming a sheath (Waldeyer's sheath). The ureters pierce the posterior aspect of the bladder, run obliquely through its wall for a short distance before terminating at the ureteric orifices. The oblique course of the ureter in the musculature of the urinary bladder is considered to assist the prevention of reflux of urine into the ureter. The longitudinally oriented muscle of the terminal part of the ureter becomes continuous with the superficial trigonal muscle. In the distended bladder, the ureteric orifices are usually 5 cm apart and in the empty bladder they are about 2.5 cm apart.

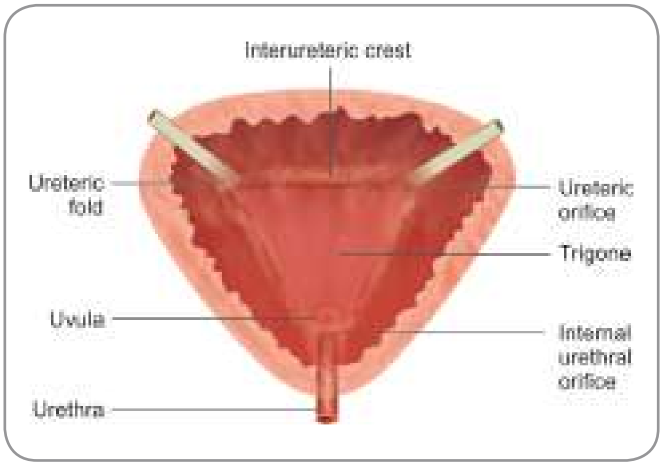


Fig. 23.9: Interior of the urinary bladder

Relations of Pelvic Part of Ureter

As the ureter runs backwards and laterally on the lateral wall of the pelvis, it lies on the fascia covering the obturator internus where it crosses several structures which lie between it and the lateral pelvic wall. In the male, it crosses the superior vesical artery, the obturator nerve and vessels and the inferior vesical artery. In the female, instead of the inferior vesical artery, it crosses the vaginal and the uterine arteries. In both males and females, it is related posteriorly to the internal iliac vessels that separate it from the lumbosacral trunk and from the sacroiliac joint. In females, the ovary lies immediately in front of the ureter and the ureter forms the posterior relation of ovarian fossa in which the ovary lies (Figs 23.10 and 23.11).

When the ureter leaves the lateral pelvic wall and turns anteromedially, it lies over the levator ani, but is separated from it by a mass of fat. The relations of this part are

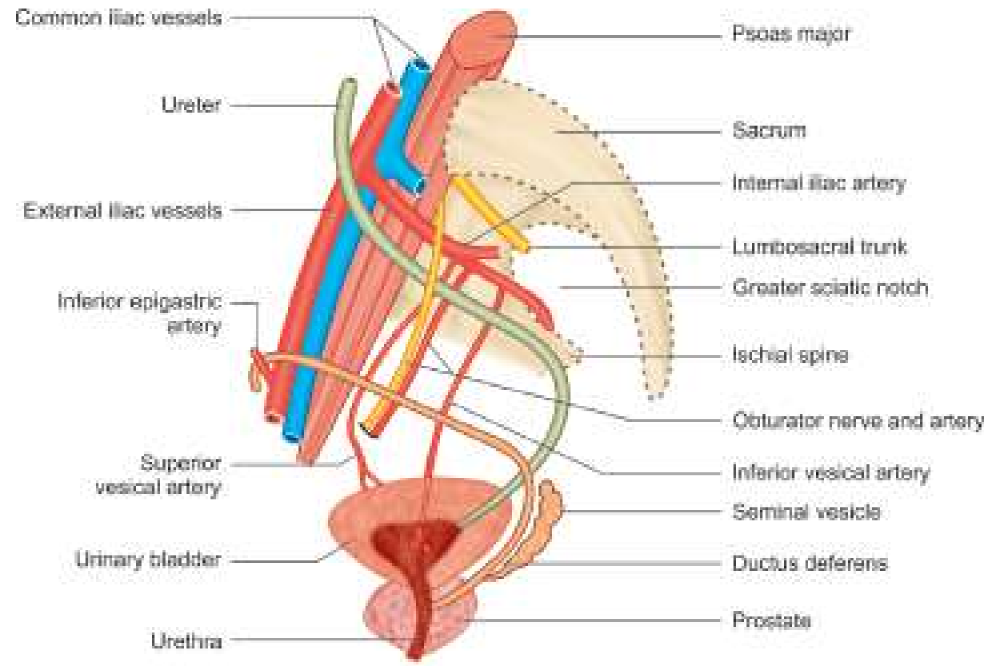


Fig. 23.10: Scheme to show the course and relations of the pelvic part of the ureter in the male

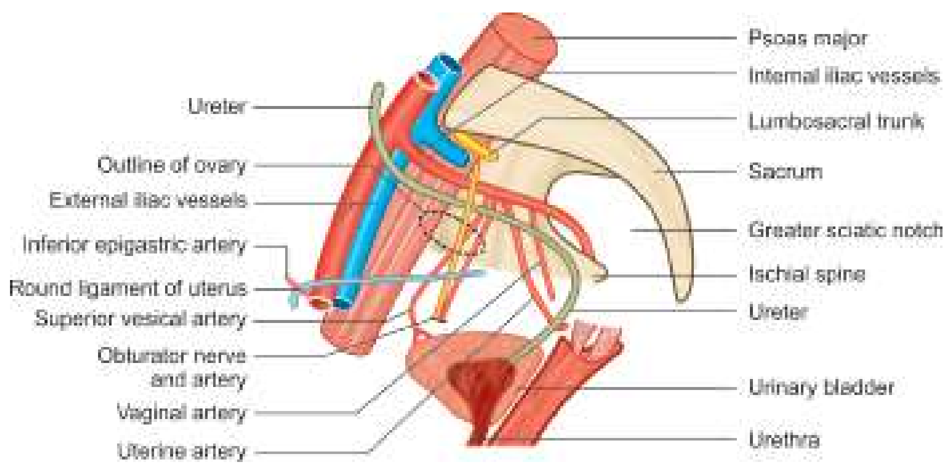


Fig. 23.11: Scheme to show the course and relations of pelvic part of the female ureter

different in the male and female. In the male, the ureter is crossed by the ductus deferens and passes just above the seminal vesicle to reach the urinary bladder. In the female, the ureter passes a short distance lateral to the cervix of the uterus just above the lateral fornix of the vagina, and then passes anterior to the vagina to reach the urinary bladder. Lateral to the cervix, the ureter is crossed by the uterine artery and the broad ligament. It is more prone to injury during hysterectomy at this point.

Constrictions of Ureter

The average diameter of the ureter is about 3 mm. It shows three constrictions which are developmental rather than mechanical. The ureter develops from the ureteric diverticulum which presents two fusiform dilatations in embryonic life—pelvic and lumbar. Later, the ends of these dilatations persist as constrictions. The sites of these constrictions are:

1. One at its upper end at the junction with the pelvis,
2. Another at its lower end at its junction with the urinary bladder and
3. Third where it crosses the brim of the pelvis.

Blood Supply

Each ureter receives branches from several ***arteries*** which lie near it. These are (from above downwards):

- The renal artery
- The abdominal aorta
- The testicular or ovarian artery
- The common iliac artery
- The internal iliac artery
- Vesical arteries
- In the female, the ureter also receives branches from the uterine artery.

A good longitudinal anastomosis exists between the various arteries supplying the ureter over its wall, which makes it safe for surgeries on ureter as there will be no compromise in blood supply.

The ***venous drainage*** corresponds to the arterial supply; the accompanying veins of the arteries drain into the corresponding veins.

Lymphatic Drainage

The ***lymphatic drainage*** of the ureter is as follows:

- The upper abdominal part drains to lateral aortic nodes.
- The lower abdominal part drains to common iliac nodes.
- The pelvic part drains into external iliac and internal iliac nodes.

Innervation

The sympathetic innervation of the ureter is from the lower three thoracic and first lumbar nerves through the renal, gonadal and superior hypogastric plexuses. The parasympathetic innervation is through the pelvic splanchnic nerves.

Although the autonomic nerves are not essential for the initiation and propagation of peristalsis in the ureter, they have a role in influencing the motility of the ureter. The autonomic nerves are predominantly sensory. Distension of the ureter by a stone causes severe pain-renal/ureteric colic. The pain is referred to the infraumbilical part of the anterior abdominal wall as it shares the innervation of the latter through the T10 to L1 segments. Pain starts on the back over lower ribs and shoots downwards and forwards to the inguinal region, scrotum, and sometimes to the front of thigh.

URINARY BLADDER

Other names: Vesica urinaria, cystis urinaria.

The urinary bladder is a hollow viscus and is a reservoir of urine. Urine is formed continuously in the kidneys and is conveyed to the urinary bladder through the ureters. The size, shape, relations and position of the bladder vary according to its content and the neighbouring viscera. When the bladder is empty, it lies in the pelvis and when distended with urine, part of it extends above the level of the pubic symphysis and comes in contact with the anterior abdominal wall. In the infant, however, the bladder lies above the level of the pubic symphysis, i.e., it is an abdominal organ rather than a pelvic one.

Capacity of Bladder

The normal capacity of the adult bladder is approximately 300 ml to 500 ml, although it normally accommodates 250 ml to 300 ml before micturition. The normal male first senses content of the bladder at 100 ml to 150 ml. Distension becomes distinctly uncomfortable in the male when the volume is about 350 ml to 400 ml. As maximum capacity is approached, involuntary micturition occurs.

In the female, the capacity is lesser than males, because of the smaller size of the bladder and differences in the anatomy of the urinary system. In infants and children, the bladder capacity in ounces can be calculated (approximate values) by adding the number 2 to the age of the child.

Presenting Parts

The empty urinary bladder is tetrahedral in shape and has four surfaces (Fig. 23.12).

The ***posterior surface*** is also called the ***base*** or ***fundus***. It is broad above and pointed below.

The ***superior surface*** faces upwards. Its posterior end is broad. Anteriorly it narrows to form the ***apex*** of the bladder.

The right and left ***inferolateral surfaces*** face downwards, laterally and forwards. They meet the superior surface at the right and left ***lateral borders.*** Posteriorly they meet the lateral margins of the base.

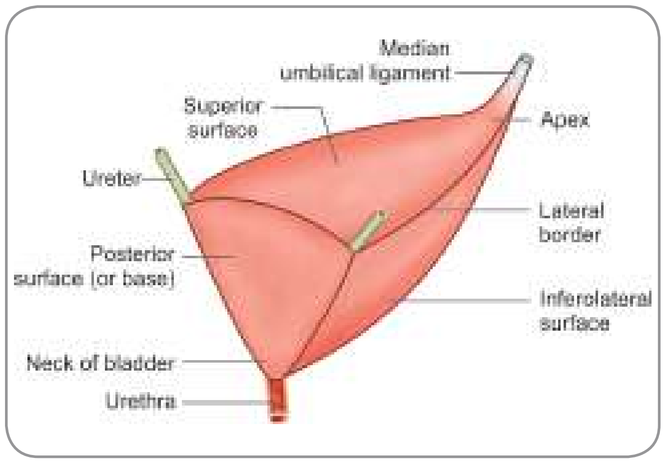


Fig. 23.12: Scheme to show the surfaces of the urinary bladder

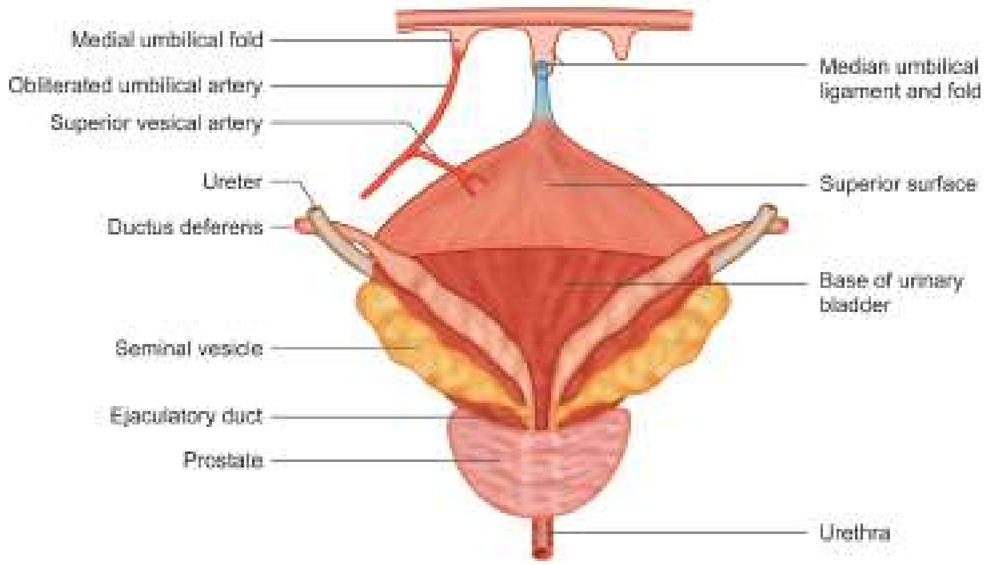


Fig. 23.13: Male urinary bladder and some related structures seen from behind

The lowest part of the bladder is called the neck. The urethra emerges from the bladder here.

The right and left ureters join the urinary bladder at its posterolateral angles. The distended bladder is ovoid and presents with antero-inferior and postero-superior surfaces, two lateral surfaces, a summit, base and neck.

Relations of the Urinary Bladder in Males (Fig. 23.13)

The ***apex*** of the bladder gives attachment to the lower end of the median umbilical ligament.

The ***superior surface*** is separated by peritoneum from part of the sigmoid colon and from coils of small intestine.

The ***inferolateral surfaces*** lie a little behind the pubic bones and the puboprostatic (or pubovesical) ligaments; still more laterally, they are behind the fasciae covering the levator ani and obturator internus muscles. They are separated from all these structures by a potential space called the space of Retzius which contains fat and the vesical plexus of veins.

The ***base*** of the bladder lies in front of the rectum, but is partly separated from it by the right and left seminal vesicles and the right and left ductus deferens. The base is covered with peritoneum up to the upper end of seminal vesicles. The part of the base below the seminal vesicle which is non peritoneal is called the ***external trigone*** of the bladder.

The ***neck*** of the bladder rests on the prostate.

Peritoneal Relations

The superior surface of the urinary bladder is covered by peritoneum. Traced anteriorly, this peritoneum becomes continuous with that lining the anterior abdominal wall and posteriorly, it passes on to the upper part of the base. It is then reflected on to the front of the rectum. The peritoneal depression thus formed between the urinary bladder and the rectum is called the ***rectovesical pouch***. Traced laterally, the peritoneum of the superior surface is reflected on to the lateral pelvic wall. This peritoneum is referred to as the ***false lateral ligament*** of the bladder.

Anteriorly, in the midline, the peritoneum is raised into a fold called the ***median umbilical fold*** over the median umbilical ligament.

In the foetus, the rectovesical pouch is much deeper and extends up to the pelvic floor. The lower part of the pouch is obliterated by fusion of the layers of peritoneum lining it. The remains of this peritoneum persist as the ***rectovesical fascia*** that separates the lower part of the base of the bladder, and lower down the prostate, from the rectum.

The inferolateral surfaces of the urinary bladder are not covered by peritoneum.

Relations of Urinary Bladder in the Female

The greater part of the superior surface of the bladder is covered by peritoneum that separates it from the body of the uterus. When traced backwards, this peritoneum is reflected on to the front of uterus at the junction of the body with the cervix. The posterior part of the superior surface of the bladder is in direct contact with the upper part of the cervix.

The relations of the inferolateral surfaces of the bladder are the same as in the male. The base of the bladder is in contact with the anterior wall of the vagina. The neck of the bladder rests on pelvic fascia.

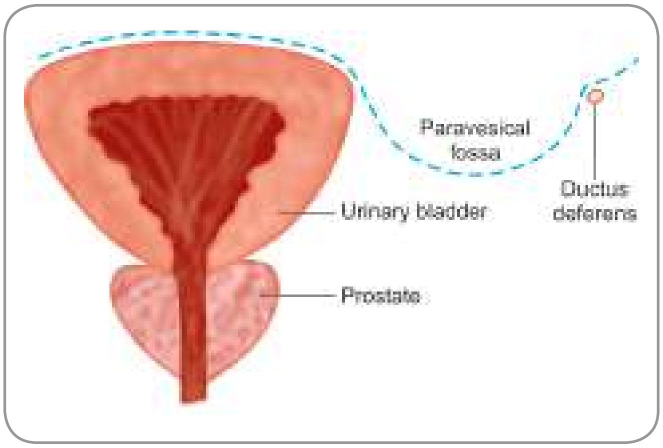


Fig. 23.14: Schematic coronal section through the urinary bladder to show the paravesical fossa

Added Information

Space of Retzius

It is a horse shoe shaped potential space (otherwise called the retropubic space and named after the 18th-19th Swedish anatomist Anders Retzius) which intervenes between the anterolateral pelvic wall and the sides of the bladder and prostate. The space allows distension of the bladder and serves as a space for retroperitoneal approach of the bladder during surgical interventions. It is bounded by:

- ***Anteriorly:*** Symphysis and body of pubis
- ***Posteriorly:*** Posterior true ligament on each side
- ***Above:*** Peritoneum of the paravesical fossa (Fig. 23.14)
- ***Below:*** Puboprostatic or pubovesical ligaments
- ***Medially:*** Inferolateral surfaces of bladder and prostate in males
- ***Laterally:*** Fascia covering obturator internus and levator ani muscles.

Relations of Distended Bladder

- The antero-inferior surface is entirely nonperitoneal and extends above the pubic symphysis.
- The postero-superior surface is mostly covered with peritoneum and is related to the sigmoid colon and small intestine in males and uterus in females.
- Summit of the distended bladder is situated behind the apex. It is separated by the prevesical pouch of peritoneum from the anterior abdominal wall.
- The lateral surfaces are partly peritoneal unlike that of empty bladder when they are entirely nonperitoneal.
- The relations of the base and the neck correspond to that of the empty bladder.

Ligaments of Urinary Bladder

The urinary bladder is kept in place by a number of so-called ligaments. Some of these are thickenings of fascia and are referred to as 'true' ligaments. Others are folds of peritoneum. These are referred to as the false ligaments.

True ligaments

- The unpaired ***median umbilical ligament*** connects the apex of the urinary bladder to the umbilicus. It is the remnant of an embryonic structure called urachus that is derived from the allantoic diverticulum.
- The fascia over the upper surface of the levator ani (pelvic fascia) is thickened anteriorly to form a pair of ***medial*** and ***lateral puboprostatic ligaments*** (in the male) or the ***pubovesical ligaments*** (in the female). Both the puboprostatic/pubovesical ligaments extend from the bladder neck. The medial puboprostatic ligament is attached to the symphysis pubis, whereas the lateral puboprostatic/pubovesical ligaments are attached to the tendinous arch of pelvic fascia.
- Laterally, the pelvic fascia stretches from the inferolateral surface of the bladder on either side to the tendinous arch of pelvic fascia. This is called the ***lateral true ligament*** of the bladder.
- The lateral margins of the base of the bladder are joined to the lateral pelvic wall by fascia surrounding the veins which pass from the bladder to the internal iliac veins. This fascia constitutes the paired ***posterior true ligaments*** of the bladder.

False Ligaments (Peritoneal Folds)

The median umbilical ligament is covered by a median fold of peritoneum called the ***median umbilical fold***.

In the foetus, the right and left umbilical arteries pass from the internal iliac arteries to the umbilicus on their way to the placenta. After birth, the proximal parts of these arteries become the superior vesical arteries and their distal parts become obliterated to form the ***medial umbilical ligaments*** which connect the superior vesical arteries to the umbilicus. They lie lateral to the median umbilical ligament and converge towards the umbilicus. These ligaments are covered by folds of peritoneum called the ***right*** and ***left medial umbilical folds***.

Peritoneum reflected from the superior surface of the bladder to the lateral wall of the pelvis is referred to as the ***lateral false ligament*** of the bladder.

Two folds of peritoneum (right and left) pass backwards from the lateral margin of the base of the bladder to the sacrum. They pass lateral to the rectum and form the lateral boundaries of the rectovesical pouch. They are called the ***sacrogenital folds*** or the ***posterior false ligaments*** of the bladder (Fig. 23.15).

Interior of Urinary Bladder

The interior of the bladder is lined by mucous membrane which is attached loosely to the underlying muscle. In the empty bladder, the mucosa shows numerous folds. These

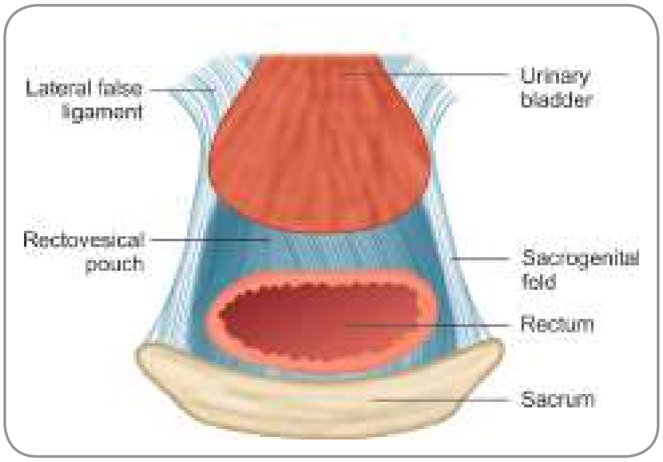


Fig. 23.15: Rectovesical pouch and sacrogenital folds as seen from above

folds get stretched out when the bladder distends. However, on the posterior wall of the bladder is a triangular area where the mucosa is adherent to the underlying muscle layer and is always smooth. This area is called the ***internal trigone of the bladder*** (or simply the trigone or the Lieutaud's trigone or Lieutaud's body). The ureters open into the urinary bladder at the upper lateral corners of the trigone while the upper end of the urethra opens at the lower angle of the trigone. The urethral opening is called the ***internal urethral orifice***. In males, a rounded elevation known as ***uvula vesicae*** projects upwards behind the internal urethral orifice. It is caused by the median lobe of prostate. The upper margin of the trigone forms a ridge stretching between the openings of the two ureters. It is called the ***interureteric crest*** (Mercier's bar or bar of bladder or plica interureterica; named after the 19th century French urologist Louis Mercier) and is formed by the continuation of the internal longitudinal muscle of the ureter into the vesical wall. The boundaries of the trigone are:

- ***Apex:*** Internal urethral orifice
- ***Base:*** Interuretric crest/bar
- ***Postero-lateral angles:*** Ureteric orifices, which are about 2.5 cm apart in empty bladder and 5 cm apart in distended bladder.

The smooth muscle of the trigone consists of two distinct layers—the superficial trigonal muscle and the deep trigonal detrusor muscle. The deep layer is indistinguishable from the detrusor layer of the rest of the bladder. The superficial trigonal muscle is a morphologically distinct layer and is continuous above with the intramural ureter and below with the smooth muscle of the proximal urethra. It extends as the urethral crest in the prostatic urethra. The trigone is the most fixed and dependent part of the bladder and is richly supplied with nerves and blood vessels. Unlike the rest of the bladder which develops from endoderm, the trigone develops from mesoderm by the incorporation of the caudal portions of the mesonephric ducts.

Histology

Histology of Urinary Bladder

The wall of the urinary bladder presents the following layers: (from outside inwards) serous, muscular and mucous layers.

- The ***serous layer*** is the same as that of peritoneum and is incomplete.
- The ***muscular layer***, otherwise called the detrusor muscle or the muscularis propria vesicae, consists of three ill defined sublayers—outer longitudinal, middle circular and inner longitudinal. It is composed of smooth muscle bundles which are arranged irregularly.
- The ***Mucous layer*** is the urothelium. It is transitional epithelium that is 4–7 layers thick. The basal layer of this epithelium consists of cuboidal cells from which the outer cells arise. The cells in the intermediate layers are polygonal and have the capacity to stretch and flatten. The superficial layer (luminal layer) is called the ***umbrella cell layer***; its cells appear dome-shaped. The cells in the superficial layer are connected by tight junctions which allow distension of the bladder without tension to the individual cells. A glycoprotein coat which gives protection to the bladder cells from contact with toxic urine is present over the surface.

Added Information

Though it is customary to describe only three layers, a layer of lamina propria is also found in the bladder. This is a layer of connective tissue and consists of capillaries, lymphatics and nerve twigs. Some strands of smooth muscle fibres may also be found, thus making up the muscularis mucosa.

During development, bits of endothelium may become separated from the surface and get embedded in the lamina propria. Such bits of endothelial tissue are called the von Brunn's nests. They may sometimes undergo degenerative changes to form cysts which are called cystitis cystica.

Bladder Neck

In both males and females, a complete ***circular collar*** of ***smooth muscles*** is present around the neck of the bladder and is a distinct entity from the detrusor muscle.

In males, the detrusor muscle of the bladder continues with that of the prostatic urethra, and the additional circular collar of smooth muscle around the bladder neck extends over the preprostatic part of urethra only. Though it is sometimes called the ***proximal urethral sphincter***, it is not a urinary sphincter and is not responsible for urinary continence. It acts as a genital sphincter and allows antegrade ejaculation of semen. It is innervated by the sympathetic nerves which on stimulation prevents reflux of semen during ejaculation.

In females, the detrusor muscle is replaced by the circular collar of smooth muscle around the bladder neck which continues with the urethral muscle. However, this muscle is not responsible for maintaining urinary continence. The bladder neck rests on the pelvic floor and is supported by the pubovesical ligaments, endopelvic fascia and levator ani which are collectively responsible for the maintenance of continence. In contrast to the males, this muscle is mainly innervated by the cholinergic nerves and not the sympathetic nerves.

Blood Supply of Urinary Bladder

Arterial Supply

The urinary bladder is supplied by the superior and inferior vesical arteries, obturator artery and a branch from the inferior gluteal artery. However, in females, the inferior vesical artery is replaced by the vaginal artery and the uterine artery also gives branches to the bladder. All are branches of the anterior division of the internal iliac artery.

Venous Drainage

Veins from the bladder form a plexus called the vesical plexus, which is situated along the inferolateral surfaces in the space of Retzius. This plexus communicates below with the prostatic venous plexus in males; veins arising from it pass backwards in the posterior ligaments of the bladder to drain into the internal iliac veins. In females, the plexus directly drains into the internal iliac veins.

Lymphatic Drainage

Lymphatics from the urinary bladder drain into the external iliac lymph nodes.

Nerve Supply

The urinary bladder is supplied by both sympathetic and parasympathetic divisions of the autonomic nervous system. Each division has both motor and sensory fibres.

Parasympathetic nerves stimulate the detrusor muscle bundles and are inhibitory to the sphincters (motor). Traditionally, sympathetic nerves are said to have the opposite effect. However, it is now believed that normal bladder function is controlled only by parasympathetic nerves and that the sympathetic nerves only have a vasomotor effect.

Sensations of bladder filling and pain travel through both sympathetic and parasympathetic nerves. Within the central nervous system, pathways for sensations of bladder filling and for pain are different. Pain from the bladder can be abolished by ***anterolateral cordotomy*** without affecting sensations of bladder filling.

Parasympathetic fibres are derived from the sacral outflow (S2, S3, S4). These fibres travel through pelvic splanchnic nerves, inferior hypogastric plexus and vesical plexus. Sympathetic fibres are derived from spinal segments T10 to L2.

Clinical Correlation

- ***Congenital malformations:*** There may be agenesis of the entire bladder or only of the sphincter vesicae. The anterior wall of the urinary bladder is absent in ***ectopia vesicae***. In this condition, the overlying anterior abdominal wall is also absent so that the posterior wall of the bladder (trigone) appears on the surface of the body. The lumen of the bladder may be divided completely by a transverse septum or partially by a constriction into upper and lower compartments. The latter condition is called ***hourglass bladder***. The bladder may communicate with the rectum, because both develop from cloaca. Congenital diverticulae may be present.
- ***Relationship of the bladder to the Anterior Abdominal Wall is of practical importance:*** Though the urinary bladder is partially in contact with the anterior abdominal wall in an infant, as the pelvis enlarges during growth, the bladder sinks into the true pelvis. Hence, in the adult, the empty bladder does not come in contact with the anterior abdominal wall. However, when it is distended, its upper part is in contact with the abdominal wall above the pubic symphysis. As the distended bladder ascends, the fold of peritoneum passing from the anterior abdominal wall to the superior surface of the bladder also rises so that no peritoneum intervenes between a distended bladder and the anterior abdominal wall. This fact is of practical importance.

  In a patient with urinary obstruction, and consequent distension of the bladder, the distension can be relieved by passing a needle into the bladder through the anterior abdominal wall just above the pubic symphysis, without compromising the peritoneal covering. The bladder can also be approached surgically through a suprapubic incision after distending it. This operation is used for removal of stones from the bladder and is called ***suprapubic lithotomy*** (Greek.lithos=stone, tome=cutting).

  The downside (of this fact) is that a distended bladder can be easily injured by a blow or stab wound in the lower part of the abdomen.
- The uvula vesicae may be enlarged in old age due to enlarged prostate. It acts as a ball valve and obstructs the flow of urine. When the patient exerts more strain to void urine, the urinary outflow becomes further diminished. As the uvula bulges into the sphincter vesicae, the sphincter mechanism is affected, leading to frequency of micturition and dribbling of urine.
- The interureteric ridge is seen as a pale band in cystoscopy, which serves as a guide to identify the ureteric orifices for retrograde pyelographic procedures and ureteroscopies.
- The ureteric orifices appear as oblique slits in cystoscopic examination. However in TB kidney, it is circular in shape due to shortening of the ureter. This condition is called ***"golf-hole ureter."***

contd…

Clinical Correlation *contd…*

- ***Effect of spinal cord injury on bladder:*** Acute injury to the spinal cord is followed by a state of spinal shock. At this stage, the muscle in the bladder wall becomes atonic, but the sphincters remain contracted. This leads to distension of the bladder. But eventually, urine dribbles out, when pressure rises to a level that cannot be opposed by the sphincters.
  A few days after the injury, the bladder begins to contract reflexly when it is full (as in an infant). This is the ***automatic reflex bladder***. It is produced by reflexes mediated by the sacral segments of the spinal cord. If these segments are damaged, reflex emptying does not occur, and there is dribbling when the bladder is distended.
- ***Other causes of urinary retention:*** Retention of urine can also occur by obstruction to the urethra from any cause. Two important causes are the enlargement of prostate (in the elderly), and a stricture of the urethra. Retention is relieved by passing a suitable catheter into the bladder through the urethra.
- Calculi (or stones; Latin.calculus=pebble) may form in the bladder and are seen much more commonly in males than in females. They can be of varying chemical composition. They can be crushed through a lithotrite introduced through the urethra. This procedure is called ***lithotripsy/litholapaxy***. The calculi can also be removed by suprapubic lithotomy.
- Injury during parturition can lead to a ***vesicovaginal fistula***.
- Infection in the bladder is called ***cystitis***.
- Neoplasms, both benign (papilloma) and malignant (carcinoma) may be seen.

Development

Development of Urinary System

The lower urinary system develops from the urogenital sinus. The cloaca, in an early embryo, receives the hind gut and gives an anterior median diverticulum called the allantois. By about the 22nd day of intrauterine life, the pronephric duct (and later the mesonephric duct) opens into its posterolaterall aspect (on either side). By about the 30th day, the urorectal septum grows down from the angle of the allantois and hindgut and separates the cloaca into a smaller dorsal hindgut part and a larger ventral urogenital part. By the 44th day , the urorectal septum completely separates the cloaca and fuses with the cloacal membrane subdividing the latter into an anterior urogenital membrane and a posterior anal membrane. The openings of the mesonephric ducts are into the urogenital sinus portion. The primitive urogenital sinus can now be subdivided into a cranial portion above the openings of the mesonephric ducts and a caudal prtion below. The cranial portion is the vesicourethral canal gives rise to the urinary bladder and the upper part of urethra. The caudal part is the definitive urogenital sinus.

URETHRA

The urethra is a tubular structure that connects the lower end or neck of the urinary bladder to the exterior. Urine stored in the bladder is passed out through it. The urethra is much longer in the male (about 20 cm) as compared to the female (4 cm). In both sexes its average diameter is about 6 mm. The course and relations of the urethra are different in the male and female. Hence, they are dealt with separately.

Male Urethra

The male urethra (urethra masculine or urethra virilise) is a common tubular passage for elimination of urine and semen (urogenital canal). It extends from the internal urethral orifice at the apex of the trigone of the bladder to the external urethral orifice close to the tip of glans penis. It is divided into two parts anterior and posterior.

- The ***anterior urethra*** is approximately 16 cm long and is confined to the perineum and penis.
- The ***posterior urethra*** is about 4 cm long and lies within the pelvis.

The average diameter of the male urethra is about 6 mm and is the narrowest at its external orifice. Except during the passage of urine, the walls of the urethra are apposed to each other with the lumen being a mere slit. The appearances seen in transverse sections through various levels of the male urethra are shown in (Fig. 23.16).

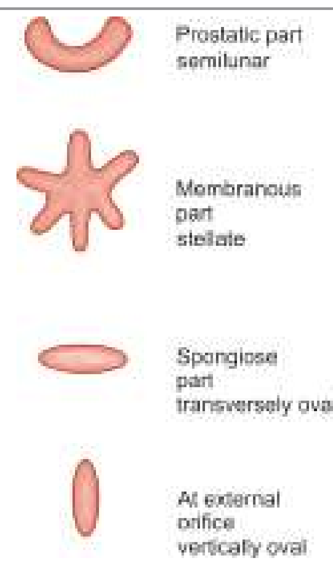


Fig. 23.16: Transverse sections through various parts of the male urethra to show the shape of its lumen

The anterior/spongiose urethra is further subdivided into ***bulbar urethra*** which lies within the bulbospongiosus and is entirely within the perineum and ***penile urethra*** which lies within the penis (corpus spongiosum). The posterior urethra is further subdivided into three parts namely, ***preprostatic urethra***, ***prostatic urethra*** and ***membranous urethra***.

Posterior Urethra

The ***preprostatic urethra*** is approximately 1 cm long and extends from the base of the bladder to the prostate.

The ***prostatic part*** continues above with the preprostatic part and descends through the prostate at the junction of anterior one-third and posterior two-thirds of the gland to become continuous with the membranous urethra at the most inferior point of the prostate. It is about 3–4 cm long. The lowermost part of the prostatic urethra is fixed by the puboprostatic ligaments and is therefore immobile. The features seen in the posterior wall of the prostatic urethra are as follows:

- On its posterior wall a median ridge of mucous membrane called the ***urethral crest*** is present; it is produced by the extension of the superficial trigonal muscle.
- On either side of the crest, the mucosa shows depressions called the ***prostatic sinuses*** in which numerous prostatic ducts open (Fig. 23.17).
- Midway between its upper and lower ends, the urethral crest bears a rounded swelling called the ***colliculus seminalis,*** otherwise called the "***verumontanum***". The colliculus presents three openings. In the midline is the opening of a small blind sac called the ***prostatic utricle***. On either side of the opening of the utricle, there are openings of the right and left ejaculatory ducts. The prostatic utricle develops from the paramesonephric ducts and is considered to be homologous to the female vagina.

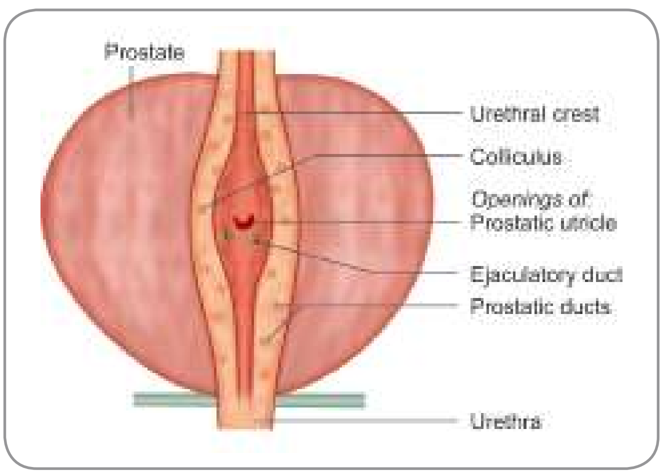


Fig. 23.17: Posterior wall of the prostatic urethra

The ***membranous*** part of the urethra is the shortest (2–2.5 cm long), least dilatable and the narrowest part of the urethra, with the exception of external urethral orifice. It descends from the prostate to the bulb of the penis passing through the perineal membrane. The muscle coat of the membranous urethra is made up of a thin layer of smooth muscle which is continuous with the prostatic urethra and a prominent outer layer of circularly oriented striated muscle fibres. Both layers together form the external urethral sphincter. The bulbourethral glands are present within these muscle fibres, the secretions of which drain into the bulbar urethra through a pair of ducts.

Anterior Urethra

The ***anterior or spongiose*** part of the urethra lies within the bulb and corpus spongiosum of the penis. It extends from the end of the membranous urethra to the external urethral orifice on the glans penis. The bulb of the penis lies in immediate contact with the lower surface of the perineal membrane. The bulb is continuous anteriorly with the corpus spongiosum. The initial part of the corpus spongiosum forms part of the 'root' of the penis and is fixed in the perineum, while its subsequent part lies in the 'free' part of the penis. Near the tip of the penis, the corpus spongiosum expands to form the glans penis.

Bulbar Urethra

The membranous urethra enters the bulb immediately after piercing the perineal membrane, anterior to the lowest level of pubic symphysis as the ***bulbar urethra***. It is the widest part and is surrounded by the bulbospongiosus muscle. The bulbourethral glands open into the bulbar urethra through the duct approximately 2.5 cm below the perineal membrane.

Penile Urethra

The continuation of the bulbar urethra is the ***penile urethra***. The penile urethra shows a dilatation at its termination within the glans penis called the ***navicular fossa.***

Histology

Male Urethra

The epithelium lining the male urethra differs in the various parts in concordance with its developmental origin.

- The preprostatic and proximal part of prostatic urethra are lined by transitional epithelium in continuation with bladder and the epithelial lining of the prostatic ducts, seminal vesicles and ejaculatory ducts.
- The part of prostatic urethra distal to the opening of the ejaculatory ducts, the membranous urethra and the major part of penile urethra are lined by stratified/pseudostratified columnar epithelium.

contd…

Histology *contd...*

- Towards the distal end of the penile urethra, the epithelium is nonkeratinised stratified squamous epithelium which becomes keratinised at the external meatus.

The epithelium especially in the penile part of male urethra presents orifices of numerous mucous urethral glands (Littre's glands) which lie in the submucosa of the urethra. It also contains number of recesses or lacunae and the largest of these is present in the navicular fossa in the glans. Catheters or other instruments introduced into the urethra may get stuck in these lacunae, hence instrumentation has to be made carefully. The epithelial cells lining the navicular fossa are glycogen rich, which provide a substrate for commensal lactobacilli; the bacilli provide for a defence mechanism (as in female vagina).

Branching tubular paraurethral glands are also present especially in the dorsal aspect; they secrete a protective mucus onto the urethral epithelial lining.

Female Urethra

The female urethra corresponds to the prostatic and membranous parts of the male urethra, and is about 4 cm long. It begins in the internal urethral orifice of the bladder, passes downwards and forwards within the anterior wall of the vagina and finally pierces the perineal membrane to open into the vestibule. The external orifice is situated in front of the vaginal opening and about 2.5 cm behind the glans clitoridis. In cross section, the female urethra is a transverse slit, but at its external orifice the slit becomes anteroposterior.

Sphincters of Urethra (Fig. 23.18)

The ***sphincter vesicae*** is a ring of smooth muscle surrounding the urethra at its junction with the bladder neck. It is described as part of the proximal urethral sphincter mechanism. However, as described earlier, this mechanism is not shown to be responsible for maintaining urinary continence.

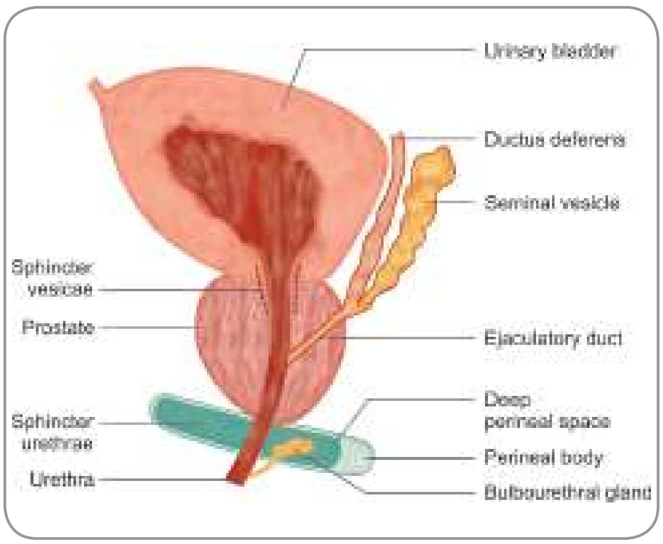


Fig. 23.18: Diagram showing the sphincters of the urethra, and the bulbourethral glands

Histology

Female Urethra

The structure of the urethra is the same as that of the males except that the mucosa is lined by non keratinised stratified squamous epithelium. However, it is lined by transitional epithelium near the internal urethral orifice. Close to the external orifice, the epithelium is keratinised.

Small mucous glands and minute urethral lacunae are seen; they open into the urethra and may give rise to diverticula. However, the prostate is replaced by the paraurethral glands (Skene's or Guerin's glands) and the bulbourethral glands are replaced by the greater vestibular glands in females. The paraurethral glands open into the urethra close to the external urethral orifice and the greater vestibular glands situated in the superficial perineal pouch open into the vagina below the hymen.

The ***external urethral sphincter/sphincter urethrae*** surrounds the membranous urethra as it passes through the deep perineal space. It is made up of striated muscle fibres. It is voluntary and is supplied by the perineal branch of the pudendal nerve.

Urinary continence at the level of the membranous urethra is mediated by the radial folds of urethral mucosa, submucosal connective tissue, intrinsic urethral smooth muscle, striated muscle fibres surrounding it and the pubourethral component of levator ani. The muscle coat of the urethra and the puborectalis surround the membranous urethra and are attached to the ischiopubic ramus and the lowest part of bladder neck.

Arterial Supply

In males, the urethra and the erectile tissue around it are supplied by the urethral artery which is a branch of internal pudendal artery and the dorsal artery of penis. In females, the urethra is mainly supplied by the vaginal artery with some contribution from the inferior vesical artery.

Venous Drainage

In males, the venous drainage of anterior urethra is to the dorsal veins of the penis and internal pudendal veins, which drain into the prostatic venous plexus. The posterior urethra drains into the prostatic and vesical venous plexuses which in turn drain into the internal iliac veins.

In females, the veins drain into the vesical venous plexus and the internal pudendal veins.

Lymphatic Drainage

In males, vessels from the posterior urethra drain mainly into the internal iliac nodes with some draining into the external iliac nodes. Vessels from anterior urethra accompany that of glans penis and mainly drain into the deep inguinal nodes, with some draining into superficial inguinal lymph nodes.

In females, the urethral lymphatics drain into both internal and external iliac nodes.

Clinical Correlation

Congenital Malformations

- The urethra may show obstruction at its junction with the bladder.
- It may show various types of duplication.
- Abnormal communications between the urethra and the rectum, vagina or ureter may be present.
- Hypospadias and epispadias may be present.

Other Correlations

- Infection in the urethra is called ***urethritis***.
- Injury or chronic infection can lead to formation of a ***stricture*** that becomes a cause of urinary retention.
- Instruments are commonly passed through the urethra to relieve urinary retention (***catheterisation***), and to visualise the interior of the urinary bladder, the ureter, or the urethra itself.
- The urethra can be injured by fall on the perineum or during instrumentation. Accidental injury to the urethra following a fall usually occurs at the junction of the membranous with the bulbar segment of the urethra. One of the complications associated with this injury is extravasation of urine. After an injury to the bulbar urethra, urine usually extravasates between the perineal membrane and the membranous layer of superficial fascia. As both are firmly attached to the ischiopubic rami, extravasated urine cannot spread laterally. Posteriorly, both the perineal membrane and the fascia are continuous around the superficial transverse perineal muscles, hence extravasated urine cannot pass posteriorly, unless the perineal membrane is breached. Hence, the extravasated urine tracks anteriorly into the loose connective tissue of the scrotum, penis and even up to the anterior abdominal wall.

Development

Development of Lower Urinary System

We already know that the mesonephric duct opens into the ***vesico-urethral canal***. The ***ureteric bud*** has been given out as a diverticulum from the mesonephric duct by about the 32nd day. After this stage, the mesonephric duct between the ureteric bud and its opening into the vesicourethral canal is the ***common excretory duct***. This common excretory duct dilates and gets absorbed into the wall of the vesicourethral canal. As a result, the ureter and the mesonephric duct open separately into the sinus. By the 35th day, the openings

contd…

Development *contd…*

are separate; each ureteric opening is cranio-lateral to the opening of the corresponding mesonephric duct. The ureteric orifices, further move cranially and laterally. The mesonephric orifices remain together but move caudally. All these changes occur due to differential growth processes in the walls of the vesico-urethral canal. With the lateral displacement of the ureteric openings, the portion of the wall of the vesico-urethral canal between them assumes a triangular shape and is called the ***primitive trigone***. By about the 50th day, the vesico-urethral canal undergoes subdivision into a dilated upper portion that forms the urinary bladder and a narrow lower portion that forms the primitive urethra. The primitive trigone becomes more triangular and has already received mesodermal contribution (probably from the mesonephric ducts). The lateral angles of the trigone are at the ureteric orifices and the apex at a newly defined internal urethral orifice (which comes about at the point of narrowing of the lower urethral part of the vesicourethral canal). The allantoic lumen obliterates and forms the ***urachus***. The primitive urethra forms, in the female, the definitive urethra. In the male, it forms that part of the ***definitive urethra*** from the internal urethral orifice to the entrance of the common ejaculatory duct.

PELVIC VISCERA OF MALE REPRODUCTIVE SYSTEM (FIG. 23.19)

DUCTUS DEFERENS

Other names: Vas deferens, spermatic duct, testicular duct.

The ductus deferens (Latin.defero=to carry away) is about 45 cm long and begins in the scrotum as a continuation of the epididymis. It passes through the inguinal canal to enter the abdomen. The part of the ductus deferens that lies in the inguinal canal forms part of the spermatic cord. At the deep inguinal ring, the ductus deferens enters the abdomen. Here it hooks around the lateral side of the inferior epigastric artery. The ductus then runs backwards and somewhat downwards, crossing medial to the external iliac vessels and comes to lie in the lateral wall of the true pelvis. As it runs backwards over the lateral pelvic wall it crosses the following:

- The umbilical artery (or superior vesical artery),
- The obturator nerve and vessels,
- The inferior vesical artery and
- The ureter.

The terminal part of the ductus deferens is shown in Figure 23.13. Having crossed the ureter, the duct runs downwards and medially behind the base of the urinary bladder, medial to the seminal vesicle where the ductus deferentia of both sides approach the midline. Just above the prostate, the ductus deferens joins with the duct of the

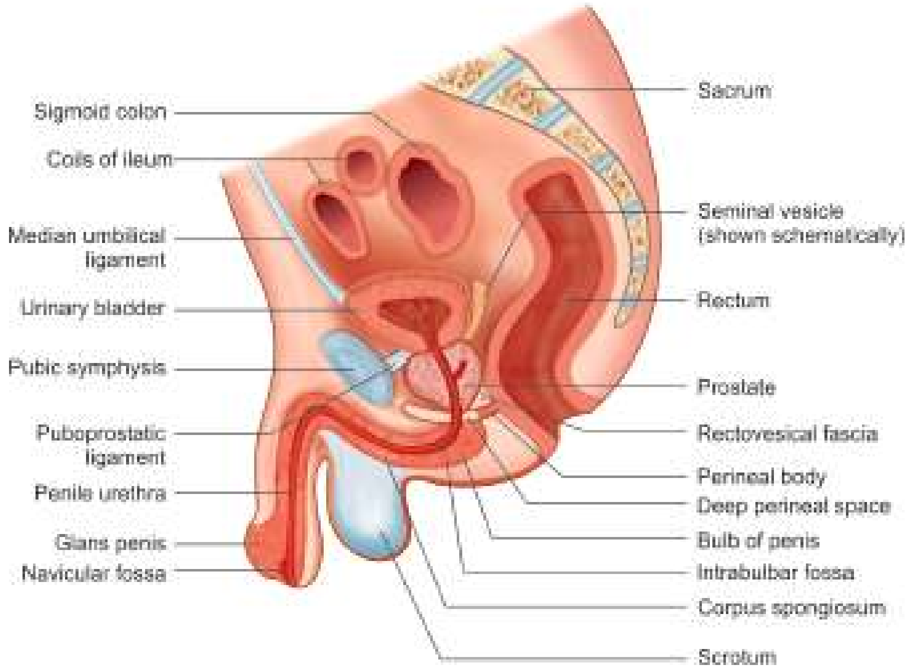


Fig. 23.19: Sagittal section through the male pelvis

ipsilateral seminal vesicle to form the ejaculatory duct. Behind the base of the urinary bladder, the terminal parts of the right and left deferent ducts along with the seminal vesicles, lie between the rectum posteriorly and bladder anteriorly.

The ductus deferens has a thick wall and a very narrow lumen. When palpated, it feels like a cord. Its initial part lying behind the testis is highly convoluted, but the rest of it is straight. The part lying behind the urinary bladder is dilated and is called the ***ampulla;*** but the terminal part of the duct again narrows down before joining the duct of the seminal vesicle. It is supplied by the artery to vas which is a branch of the superior or inferior vesical artery.

Histology

On cross-section, the ductus presents three layers from outside inwards—areolar, muscular and mucous layers. The areolar layer is formed by the condensation of loose connective tissue. The muscular layer consists of ill defined outer longitudinal and inner circular layers of smooth muscle. The mucous membrane shows a number of longitudinal folds so that the lumen appears stellate in cross-section. The epithelium is lined by non ciliated simple columnar secretory epithelium in most parts. In the extra abdominal part, it becomes ciliated.

Development

Development of Male Reproductive Organs

The primordia of the sex glands are the genital ridges which appear as thickenings of the coelomic epithelium on the medial aspect of the mesonephros by around the 30th day of intrauterine life. The primordial germ cells migrate to this area. Thus both the genital ridge cells, primordial germ cells along with the coelomic epithelium go into the formation of the sex gland or gonad. Until the 46th or 47th day, changes in both sexes are the same and the embryo cannot be distinguished by its sex. By the 40th day the gonadal blastema develops cords of cells called ***sex cords***. Fibrous tissue bundles separate these cords. Later, the primordial germ cells get absorbed into the sex cords, which subsequently become canalised to form the seminiferous tubules. the cords which do not canalise remain as interstitial cells. the cords form a network in the region of the mesorchium and this becomes the rete testis. Some of the mesonephric tubules which join the rete testis do not develop other characteristics but communicate with the mesonephric duct (as vasa efferentia). This establishes communication of the rete testis with the mesonephric duct. The mesonephric duct opens into the ventrolateral part of cloaca. The part of cloaca caudal to the origin of the ureter gets absorbed into the primitive urogenital sinus (ventral portion of cloaca). Now both the mesonephric duct and the ureter open separately into the cloaca. the upper end of the mesonephric duct gets connected to the seminiferous tubules and rete testis through the vasa

contd...

Development *contd...*

efferentia (mentioned above). The part of the mesonephric duct immediately below the vasa efferentia connection elongates and coils to form the epididymis. The remainder of the duct develops a muscular coat and becomes the vas deferens. Close to its opening into the urogenital sinus, the duct develops an ampulla and a diverticulum arises from this ampulla. The diverticulum becomes the seminal vesicle. the part of the duct between the seminal vesicle and the urethra becomes the ejaculatory duct. The upper blind end of the mesonephric duct persists as appendix epididymis.

Dissection

Before embarking on a mission to do dissection of the pelvis, study a prosected specimen carefully. Note the peritoneal reflections and folds. Then proceed to identify the pelvic mesocolon in the cadaver that you are dissecting. Locate and identify the rectum. Study the unique peritoneal relation that the rectum has. It has no mesentery, no taeniae, no sacculations and no appendices epiploicae. Study its flexures. Then trace the various vessels of the region. Then focus on the urinary bladder. See the peritoneal folds and fossae. Utilise the opportunity to observe the relationship of the seminal vesicles to the urinary bladder and the ejaculatory ducts. Observe the prostate gland. Review with your theory knowledge.

Clinical Correlation

Bilateral ligation of the vas deferens (called vasectomy or gonangiectomy) is the method of choice adopted for permanent sterilisation in males. It prevents the sperms from reaching the semen. However, it takes about three months for the sperm count to become negative after the surgery, as the sperms produced already are in the tract. Hence, it is advised to use some other method of contraception to prevent pregnancy in the partner during this time. As the growth of the interstitial cells of testis are not affected, the libido of the male who has undergone vasectomy is unaffected.

SEMINAL VESICLES

The right and left seminal vesicles lie posterior to the base of the urinary bladder, between it and the rectum. Each vesicle is about 5 cm long. The lower ends of the right and left seminal vesicles lie close together near the median plane. From here, each vesicle passes upwards and laterally so that the upper ends of the two vesicles are far apart, and lie near the ureters. When dissected out, each seminal vesicle is seen to be a long tube convoluted upon itself. One end of this tube is blind. The duct emerges at the lower end of the seminal vesicle. This duct joins the corresponding ductus deferens to form the ejaculatory duct. When uncoiled, the length of the vesicle increases to 15 cm.

The seminal vesicles secrete a viscid, yellowish white alkaline fluid rich in prostaglandin and fructose; this fluid forms the bulk of semen. They do not act as a reservoir for semen but expel their contents only during ejaculation.

Each seminal vesicle is supplied by the inferior vesical and middle rectal arteries. The veins accompany the arteries. Lymphatics from the seminal vesicle drain into the internal and external iliac lymph nodes.

Histology

The wall of the seminal vesicle presents three layers from outside inwards - areolar, muscular and mucous layers. The areolar layer is formed by condensation of connective tissue. The muscular layer comprises an outer longitudinal and an inner circular layer of smooth muscle. The mucous membrane is thrown into numerous thin folds forming a network like appearance. It is lined by simple columnar epithelium with occasional goblet cells.

EJACULATORY DUCTS

Each ejaculatory duct is about 2 cm long and is formed by the union of the ductus deferens and the duct of the seminal vesicle. It passes downwards and forwards through the substance of the prostate to open on the colliculus seminalis just lateral to the aperture of the prostatic utricle.

PROSTATE

Other name: Glandula prostatica.

The prostate (Greek.pro= in front, stata=standing; meaning 'one standing before') is a pyramidal fibromuscular gland which surrounds the proximal part of urethra from the base of the bladder to the membranous urethra. It lies behind the lower part of the symphysis pubis, and in front of the rectum. It is traversed by the ***prostatic part of the urethra***, and the ***ejaculatory ducts***. The ***prostatic utricle*** also extends into it. The prostate is broadest above (***base***) and narrowest below (***apex***). Its width at the base is about 4 cm; its vertical diameter is about 3 cm and the anteroposterior diameter is about 2 cm.

The prostate is surrounded by a fibrous ***capsule*** that is closely adherent to the gland (called the true capsule). It is structurally continuous with the stroma of the gland. Outside the capsule is a fibrous ***sheath*** that contains the dense venous plexus and is part of the pelvic fascia (this is the false capsule). The posterior part of the fibrous sheath, which separates the prostate from the rectum, is formed by the rectovesical fascia (or fascia of Denonvilliers).

The prostate has five surfaces.

- The ***superior surface,*** or base, is in contact with the neck of the urinary bladder.
- The ***posterior surface*** is in contact with the rectum and can be palpated through the latter.
- The ***anterior surface*** is connected to the pubic bones by the right and left puboprostatic ligaments. The dorsal venous complex (or the Santorini's plexus) is situated between this surface and the pubis.
- The right and left ***inferolateral surfaces*** are in contact with the corresponding levatores ani muscles. These parts of the levatores ani muscles are often referred to as the ***levatores prostatae***.

The substance of the prostate is often described as being divided into a number of lobes, but this is a subject on which there is considerable controversy.

Anatomically, the prostate is divided into three lobes—one median and two lateral lobes. In the posterior surface, a depression is formed where the two ejaculatory ducts pierce the gland. This depression divides the posterior surface into a smaller superior area and larger inferior area. The superior area is called the median lobe which lies between the urethra and two ejaculatory ducts. The lower area is subdivided by a superficial median sulcus on the posterior surface into two lateral lobes. The lateral lobes cover the sides of the urethra and are connected to each other in front of the urethra by a fibromuscular isthmus. The two lateral lobes are also continuous with each other behind the urethra and deep to the sulcus (Fig. 23.20).

Surgically, five lobes are described. The ***median lobe*** is almost the same as that of the anatomical median lobe. The surgical right and left ***lateral lobes*** are separated in front by an ***anterior lobe*** and behind by a ***posterior lobe***. The anterior lobe is the region of isthmus and the posterior lobe is that part of the lateral lobes which are connected behind the urethra. The region of isthmus contains glands in foetal life only, hence is not considered as a separate lobe anatomically in adult life (Fig. 23.21).

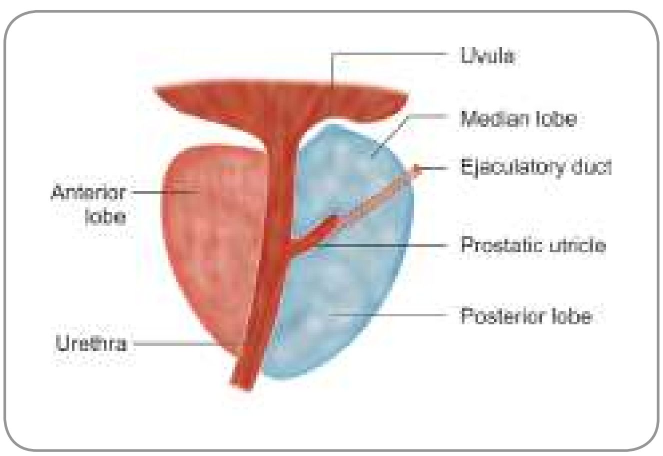


Fig. 23.20: Sagittal section through the prostate to show its lobes

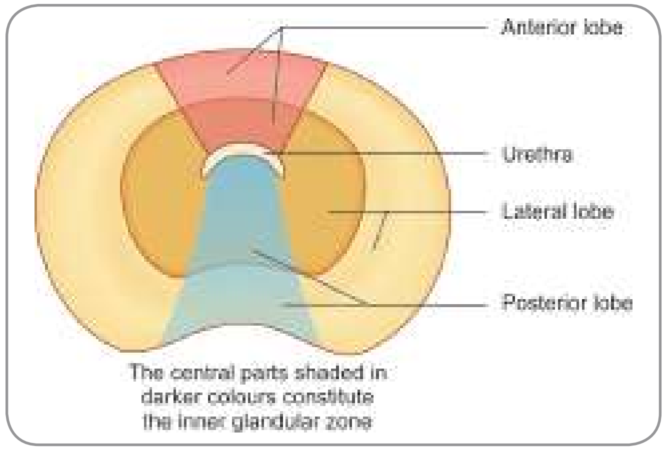


Fig. 23.21: Transverse section through the prostate to show its lobes

Arterial Supply

The prostate is supplied by branches of the inferior vesical, middle rectal and internal pudendal arteries.

Venous Drainage

The veins form a prostatic plexus within the pelvic fascia (false capsule). The venous plexus receives the deep dorsal vein of penis and communicates above with the vesical plexus. Finally the blood drains into the internal iliac veins through the posterior ligaments of the bladder.

A few veins from the prostate pass backwards through the anterior sacral foramina to drain into the internal vertebral venous plexus (also called the para vertebral veins of Batson). This backflow occurs especially during increased intra abdominal pressure such as in coughing, micturition, defaecation, etc. It explains the metastasis of malignancy to vertebrae in carcinoma prostate.

Lymphatic Drainage

The lymphatics drain into the internal and external iliac nodes.

Nerve Supply

The nerves are autonomic, with the sympathetic nerves reaching the prostate through the inferior hypogastric plexus and parasympathetic through the pelvic sphlanchnic nerves.

Development

Development of Urinary System and Part of Genital System

Fate of Definitive Urogenital Sinus

It differs in the two sexes. The definitive urogenital sinus has an upper portion called the ***pars pelvina*** and a lower portion called the ***pars phallic***. In the male, the pars pelvina gives rise

contd...

Development *contd…*

to the lower part of prostatic urethra and the membranous urethra. In the female, the pars pelvina may contribute a little to the lowest portion of the definitive urethra and to the lower part of vagina.

Development of Prostate Gland

A set of solid buds arise from the endodermal part of primitive urethra and from the adjacent part of primitive urogenital sinus. These buds grow into the surrounding mesenchyme which contributes to the connective and muscular tissue elements of the prostate. The buds arise from all sides of the urethra and are arranged in five groups- anterior, posterosuperior, posterior and two lateral groups. The posterior group arises from the urogenital sinus and develops a separate capsule during development. This is the part which is rarely involved in prostatic hypertrophy but is more frequently affected by malignancy.

In the female, the same set of buds arises but do not undergo complete maturation. Some of the buds arising from the primitive urethra form the urethral glands and those arising from the urogenital sinus form the para urethral glands of Skene.

Histology

The substance of the prostate consists of glandular tissue, masses of which are separated by fibromuscular septa.

The ***fibrous tissue*** is the thin firm capsule which is continuous with the fibromuscular septa that separates the glandular elements.

contd…

Histology *contd...*

The ***muscular tissue*** consists of smooth muscles. The muscles are arranged as an outer sheet beneath the true capsule which is continuous with the detrusor muscle of the bladder and an inner sheet around the urethra.

The ***glandular*** component is made up of 30–50 compound tubule-alveolar glands which are embedded in the fibromuscular tissue. The glandular tissue is seen in the form of numerous follicles lined by columnar epithelium. The epithelium is thrown into numerous folds along with the underlying connective tissue. The follicles drain into 12-20 excretory ducts that open into the prostatic urethra.

The ducts are lined by a superficial columnar epithelium and deeper cuboidal epithelium. Small rounded masses of uniform or lamellated structure are found within the lumen of the follicles called as corpora amylacea or amyloid bodies. They are more abundant in older individuals.

The glandular tissue is poorly developed at birth. It gradually undergoes growth, but this growth becomes much faster at the time of puberty. After the age of fifty years, the prostate may undergo atrophy. In some persons it undergoes benign hypertrophy.

On the basis of the size and nature of glands, the prostate is divided into an outer (or peripheral) zone and an internal zone (central zone). In addition, an innermost zone surrounding the urethra is also described.

The glands in the outer zone are the main prostatic glands which open into the prostatic sinuses through long ducts. The internal zone comprises of submucous glands which have shorter ducts. The innermost glands open directly into the urethra.

Clinical Correlation

The two most important clinical conditions affecting the prostate are enlargement in old age [called the benign prostatic hypertrophy (BPH)] and carcinoma.

Benign hypertrophy of prostate: Benign hypertrophy of prostate is due to the formation of an adenoma. This condition occurs most frequently in the median lobe; and somewhat less frequently in the inner parts of the lateral lobes. The region corresponds to the inner central zone, which is therefore called the ***adenomatous zone***. In contrast, the outer peripheral zone is frequently the site of carcinoma and is, therefore, called the ***carcinomatous zone***.

- The median lobe produces a projection called the uvula vesicae on the interior of the urinary bladder just behind the internal urethral orifice. With enlargement of the median lobe, the uvula also enlarges and may form a flap that covers the internal urethral meatus and obstructs it. The enlarging uvula may insinuate itself into the internal urethral sphincter and thus make it inefficient. If this happens, urine keeps entering the prostatic urethra resulting in a constant desire to micturate. The enlarged uvula leads to the formation of a pouch that is not emptied during urination leading to stagnation of urine. Obstruction to flow of urine is also caused by distortion of the prostatic urethra produced by enlargement of prostate.
- One of the important symptoms of prostatic enlargement is repeated and frequent desire to pass urine but with difficulty in doing so. The condition can also lead to urinary retention.
- Traditionally an enlarged prostate is treated by surgical removal (prostatectomy). In prostatectomy, the organ can be approached either through the urinary bladder (***transvesical prostatectomy***), or the retropubic region without entering the bladder (***retropubic prostatectomy***), or through the perineum (***perineal prostatectomy***).
- However, in recent times, the operation of choice is removal through an instrument passed through the urethra. This is called ***Transurethral Resection of Prostate*** (TURP) in which the verumontanum (colliculus seminalis) serves as a guide to identify the urethral sphincter.
- In traditional removal of the prostate, as it is advised not to disturb the venous plexus present within the condensation of pelvic fascia (false capsule), the prostate is removed from within its capsule (enucleation). Carcinoma of prostate is common and usually occurs in the outer peripheral zone.
- Infection of prostate is called prostatitis, which may be acute or chronic. Prostatitis may sometimes be tubercular.

contd…

Clinical Correlation *contd...*

Bulbourethral Glands

The bulbourethral glands are paired glands located in the deep perineal space on either side of the membranous urethra and also along the bulbar urethra in males. They are embedded within the fibres of the sphincter urethrae. Each gland gives off a long duct of about 3 cm that pierces the perineal membrane to enter the superficial perineal space. Here it ends by opening into the bulbar urethra about 2.5 cm below the perineal membrane. The greater vestibular glands in females are homologous to the bulbourethral glands of males.

Multiple Choice Questions

1. The longitudinal muscle layers which pass from the rectum to the perineal body constitute the:
   a. Rectourethralis
   b. Rectococcygeus
   c. Rectoanal sling
   d. Puborectalis

2. One of the following is not a constriction point of the ureter. Which is it?
   a. Pelviureteric junction
   b. Ureterovesical junction
   c. Brim of pelvis
   d. Over the levator ani

3. The lateral true ligaments of the bladder are the:
   a. Lateral condensations of pelvic fascia
   b. Lateral peritoneal folds
   c. Sacrogenital folds
   d. Pubovesical ligaments

4. Navicular fossa is found in:
   a. Preprostatic urethra
   b. Prostatic urethra
   c. Bulbar urethra
   d. Penile urethra

5. Few of the Prostatic veins pass through which foramen/foramina to reach the internal vertebral venous plexus?
   a. Posterior sacral foramina
   b. Obturator foramen
   c. Greater sciatic foramen
   d. Anterior sacral foramina

ANSWERS

1. a **2.** d **3.** a **4.** d **5.** d

Clinical Problem-solving

Case Study 1: A 54-year-old man presents with a complaint—passage of blood during passage of faeces. He has no pain. He has been having this problem for some years.

- What is the most probable diagnosis?
- What is the anatomical basis for this condition?
- What are the causes which predispose to this condition?

(For solutions see Appendix).

Chapter **24**

Pelvic Viscera—II: Viscera of Female Reproductive System

Frequently Asked Questions

- Discuss the uterus and its supports in detail.
- Write notes on: (a) Uterine tubes, (b) Supports of uterus, (c) Blood supply of uterus.
- Write briefly on: (a) Broad ligament, (b) Anteversion, (c) Cervix.

In the true pelvis, viscera of gastrointestinal, urinary and reproductive systems are seen. The viscera of the digestive system are the sigmoid colon, rectum and anal canal. In addition, some coils of small intestine are also present in the pelvis. The viscera of the urinary system are the pelvic parts of ureters, urinary bladder and urethra. The main reproductive organs seen in the male pelvis are the pelvic part of ductus deferens, seminal vesicles and prostate gland and in the female pelvis are the uterus, uterine tubes and vagina (Fig. 24.1). In this chapter, we shall be dealing with the viscera of the female reproductive system.

FEMALE REPRODUCTIVE ORGANS (FIG. 24.2)

The female reproductive organs consist of the female internal and external genitalia and the mammary glands. The female external genitalia have been considered along with other structures in the perineum in Chapter 15. The mammary glands are described along with the pectoral region in the section on upper limb.

The female internal genitalia consist of:

- Ovaries;
- Uterus and uterine tubes and
- Vagina.

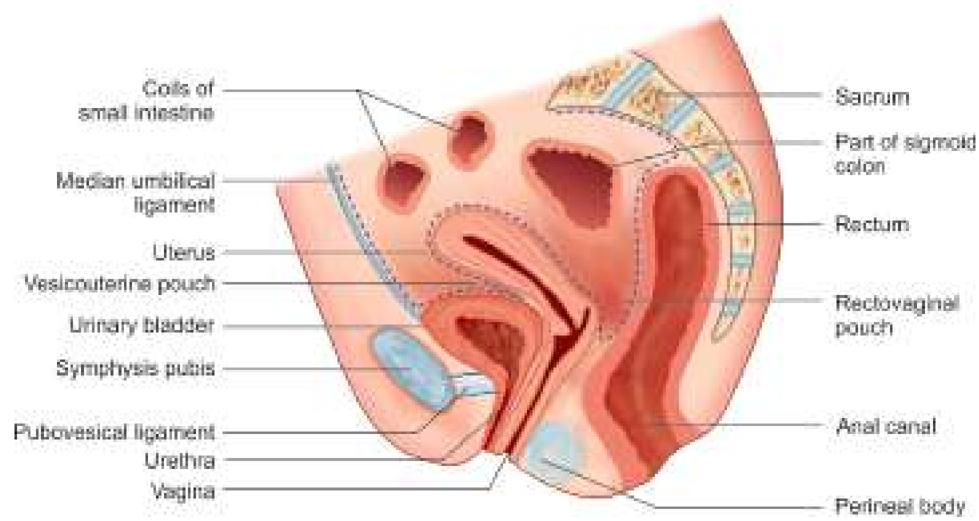


Fig. 24.1: Sagittal section through female pelvis

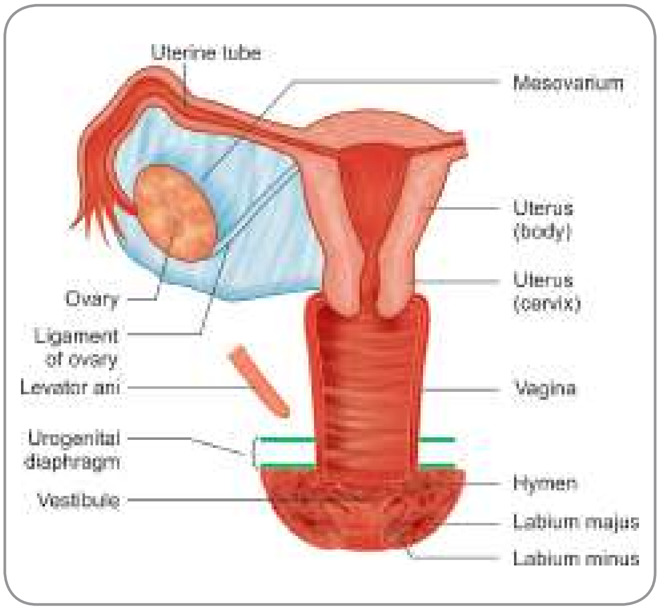


Fig. 24.2: Scheme to show the female reproductive organs

Dissection

Study the female reproductive organs in a prosected specimen. In a sagittal section of pelvis, note the anteflexion and anteversion curves of uterus. Identify the various parts of the uterus. Study the broad ligament. If possible, try to clean up the broad ligament in a partially dissected specimen. Clean up the uterine tubes and then locate the ovary. Study its relations. Alongside, study the ureter and its relations. Trace the various blood vessels of the region. Review the supports of uterus and relations of vagina with your theory knowledge.

Development

The paramesonephric duct or the Mullerian duct appears as an epithelial invagination into the mesenchyme by about the 4th week of intrauterine life. This invagination is lateral to the cranial end of the mesonephric duct. The caudal tip of the invagination is solid and keeps burrowing into the mesenchyme lateral and parallel to the mesonephric duct. The cranial end of the invagination has an opening (the original point of invagination) and as the duct elongates, the cranial part develops a lumen in continuity with this opening. At the caudal end of the mesonephric duct, the paramesonephric duct crosses to the medial side, grows caudo-medially and eventually meets up with the fellow of the opposite side. This fusion occurs within the urogenital septum (that is where both the ducts have reached after their caudo-medial journey). The fusion is initially partial and the two lumina are partially separated. However, by the fourth month, the fusion is complete and a single cavity called the uterovaginal canal is formed. The caudal end of the uterovaginal canal strikes the posterior wall of the urogenital sinus and produces a tubercle called the Mullerian tubercle. Each paramesonephric duct now has three portions:

contd...

Development *contd...*

cranial vertical portion, intermediate transverse portion and caudal vertical portion. the first two form the uterine tube. the third is part of the uterovaginal canal. Several changes occur at the point where the Mullerian tubercle is situated. Proliferation of the tip of the uterovaginal canal occurs; a solid vaginal cord is formed and leads to lengthening. Endodermal evaginations from the urogenital sinus occur producing the sinovaginal bulbs. These bulbs contribute to the lower portion of the vagina. The part of urogenital sinus cranial to the sinovaginal bulbs narrows and forms the female urethra.Canalisation takes place later. Curves of anteflexion and anteversion occur by the fifth-sixth months of intrauterine life. In foetal life, the cervical portion of uterus is larger than the body. Fusion of paramesonephric ducts, descent of the uterine tubes, regression of the mesonephric ducts are the overall changes seen and they contribute to the formation of the broad ligament. The original abdominal ostium of the cranial end of the paramesonephric duct forms the ostium of the uterine tube.

OVARY

Other names: Ovarium, ootheca, oophoron.

The ovaries are a pair of female reproductive organs and are the female gonads. The female gametes, called the ***ova*** (singular=ovum, Latin.ovum=egg), are produced in them. Each ovary is oval in shape. It is approximately 4 cm in length, 3.0 cm in width, and 2 cm in thickness in reproductively mature women. It is covered by germinal epithelium that is continuous with the peritoneum. In the adult non pregnant state, the ovaries lie on each side of the uterus, close to the lateral pelvic wall. In embryonic and early foetal life, the ovaries are situated in the lumbar region near the kidneys. They gradually descend along the gubernaculum, stopping at the lesser pelvis.

The ovary is attached to the posterosuperior aspect of the broad ligament by a fold of peritoneum called the ***mesovarium***. The broad ligament is a fold of peritoneum that stretches from the side of the uterus to the sidewall and floor of the pelvis. The part of the broad ligament between the attachment of the mesovarium and the lateral wall of the pelvis is called the ***suspensory ligament of the ovary*** or the ***infundibulo pelvic ligament of ovary***. The ovarian vessels and nerves pass through the suspensory ligament. Because of its peritoneal attachments, the ovary has considerable mobility leading to variations in its orientation.

In nulliparous women (women who have never been pregnant), the orientation of the ovary is as follows:

- The long axis of the ovary is vertical. It has upper and lower ends, medial and lateral surfaces, and anterior and posterior borders.

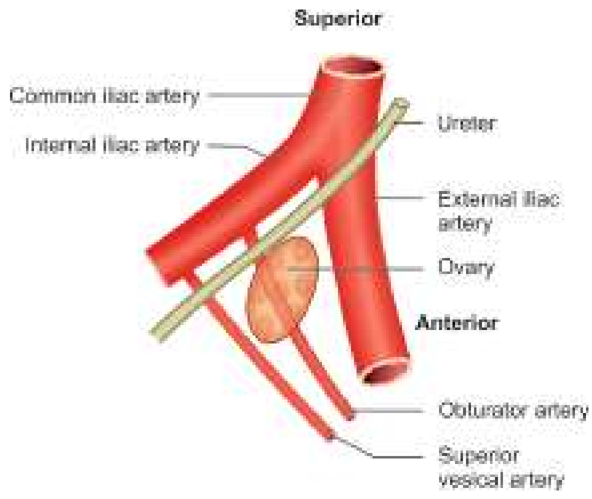


Fig. 24.3: Boundaries of ovarian fossa

- The ***anterior border*** gives attachment to the mesovarium and is, therefore, also called the ***mesovarian border***.
- The ***posterior border*** is also called the ***free*** border.
- The ***lateral surface*** of the ovary lies in contact with the peritoneum covering the lateral wall of the pelvis. It lies in a depression called the ***ovarian fossa***. The ovarian fossa is bounded (Fig. 24.3):
  - Anteriorly, by the external iliac vessels;
  - Posteriorly, by the ureter and internal iliac vessels;
  - Inferiorly, by the superior vesical artery which is the persisting proximal part of the umbilical artery.
- The obturator vessels and nerve cross lateral to the ovarian fossa.
- The ***medial surface*** is in contact with the terminal part of the uterine tube.
- The ***upper pole*** is in intimate contact with the uterine tube and is, therefore, called the ***tubal end***. It is directed upwards, a little forwards and laterally. It lies close to the external iliac vessels.
- The ***lower pole*** is directed downwards, and somewhat backwards and medially. It gives attachment to the ***ligament of the ovary or ovarian ligament.*** The ovarian ligament passes in the interval between the two layers of the broad ligament and is attached to the lateral angle of the uterus posteroinferior to the uterine tube.

Development

The primordia of the sex glands are the genital ridges which appear as thickenings of the coelomic epithelium on the medial aspect of the mesonephros by around the 30th day of intrauterine life. The primordial germ cells migrate to this area.

contd...

Development *contd...*

Thus both the genital ridge cells and the primordial germ cells along with the coelomic epithelium go into the formation of the sex gland or gonad. Until the 46th or 47th day, changes in both sexes are the same and the embryo cannot be distinguished by its sex. By the 40th day the gonadal blastema develops cords of cells called sex cords. The sex cords, soon become broken up into isolated masses; however, they continue to be attached, atleast partially to the germinal epithelium. No tunica albuginea is formed. A rudimentary network of the sex cords extends into the region of the mesovarium forming the rete ovarii. The masses of sex cords form the primordial follicles. Stromal mesenchyme gives rise to the interstitial cells.

Structure of Ovary

The surface of the ovary is covered by a single layer of cuboidal epithelium and is dull white in colour in contrast to the shiny smooth peritoneal covering of the mesovarium with which it is continuous. The surface epithelium is sometimes called the ***germinal epithelium***, which is essentially a misnomer because it is not a source of germ cells. Immediately beneath the surface epithelium, a tough collagenous coat called the ***tunica albuginea*** which surrounds the ovarian substance is present.

The substance of the ovary is divisible into an outer ***cortex*** containing ***ovarian follicles*** and an inner ***medulla*** which receives the ovarian vessels and nerves at the hilum. The cortex forms the major bulk of the adult ovary.

The ovarian cortex contains the follicles in various stages of development, corpora lutea and their degenerative remnants depending on the stage of the menstrual cycle. The various components are embedded in a dense stroma.

The stromal cells give rise to the follicular cells which surround the developing ovum. The developing ova surrounded by the follicular cells are called the ovarian follicles. These can be classified into primordial follicle, primary follicle, secondary follicle and tertiary follicle.

The developing ovum (primary oocyte) with one layer of flat follicular cells surrounding it forms the ***primordial follicle***. Numerous primordial follicles are present at birth. They develop further only with the onset of puberty. During the reproductive period of a woman's life, a series of changes occur every month in which the primordial follicles undergo further development to form the primary, secondary and tertiary follicles.

When the flat follicular cells lining the primordial follicle become cuboidal or columnar, the follicle is called the ***primary follicle***. The follicular cells of the primary follicle proliferate to form several layers collectively called the ***membrana granulosa***. The cells are now called granulosa cells. As the follicle expands, the stromal cells immediately surrounding the membrana granulosa condense to form a covering for the follicle; this covering is the theca interna (theca means a sheath or capsule; Greek. theke=box). The theca interna is responsible for secretion of oestrogen. Outside the theca interna, another layer is formed by the condensation of fibrous tissue; this is the theca externa. The theca interna and externa together form the theca folliculi. At about the same time, a homogenous membrane called the zona pellucida appears in the primary follicle between the plasma membrane of the oocyte and the surrounding granulosa cell layer.

The granulosa cells continue to increase and start separating from one another partially, leading to the formation of a follicular cavity called the ***liquor folliculi*** or ***antrum folliculi***. The follicle is now a ***secondary follicle or antral follicle***. The follicular cavity further increases in size. The wall of the follicle formed by the granulosa cells becomes thinner and the oocyte lies eccentrically in the follicle surrounded by some granulosa cells.The granulosa cells which surround the oocyte constitute the cumulus oophoricus and the cells which anchor the oocyte to the follicular wall constitute the discus proligerus. The thecal layers become distinct and the theca interna starts secreting oestrogen.

The secondary follicle further increases in size and forms the ***tertiary follicle*** or the ***Graafian follicle*** which becomes so big that it forms an elevation on the surface of the ovary and with further enlargement, ruptures shedding the ovum. This process of shedding is called ***ovulation***. The region of the developing follicle is overlapped by the fimbriated end of the uterine tube that receives the ovum discharged from the ovary. After the ovum is discharged, the remaining part of the ovarian follicle is converted into a yellowish body called the ***corpus luteum***. Because of repeated ovulations occurring every month, the smooth surface of ovary seen in prepubertal life becomes rough and scarred.

After the ovum is discharged, the follicle initially collapses due to sudden reduction of pressure. Later the follicular cells again increase in their size with a yellow pigment filling the cytoplasm; the cells are now called the ***luteal cells***. This structure (remnant of the follicle) is called the corpus luteum (Latin.luteus=yellow) and secretes progesterone and oestrogen. Further fate of corpus luteum depends on the fertilisation status. If the ovum is fertilised, the corpus luteum further increases in size and forms the corpus luteum of pregnancy and continues to secrete progesterone until the placenta takes over (about 8–10 weeks of gestation). If the ovum is not fertilised, it persists for 12–14 days secreting progesterone and then regresses and becomes a mass of fibrous tissue called the corpus albicans (Latin. albus= white).

The series of changes that begin with the formation of the ovarian follicle and end with the degeneration of the corpus luteum constitute the ovarian cycle. In every ovarian cycle, atleast 20–50 primordial follicles are recruited to mature, but only one attains the final maturity. The rest of the follicles which do not reach maturity also degenerate; this process is called follicular atresia. Though the granulosa cells and the ova degenerate, the theca interna cells persist as interstitial glandular cells and secrete oestrogen for some time. At this stage, remnants of such follicles are called ***corpora atretica***. Later, by the end of menstrual cycle, even these degenerate and form another mass of fibrous tissue indistinguishable from corpora albicans.

Arterial Supply

The ovary is supplied mainly by the ovarian artery which is a branch of abdominal aorta supplemented by some branches of the uterine artery.

Venous Drainage

A number of veins arise from the ovary and form the pampiniform plexus from which a single ovarian vein arises from each side. The ovarian vein then passes through the suspensory ligament and drains into the inferior vena cava in the right side and left renal vein in the left side.

Lymphatic Drainage

Lymph vessels from the ovary pass along the ovarian vessels to the preaortic and lateral aortic lymph nodes.

Nerve Supply

The ovary is innervated predominantly by sympathetic nerves from T10 to T11 segments which reach it along the ovarian vessels.

Clinical Correlation

- ***Congenital malformations :*** The ovary may be absent, or may be duplicated. It may undergo abnormal descent into the inguinal canal or even into labium majus.
- The ovary may be the site of carcinoma. Peculiar tumours called ***teratomas*** may occur. They may contain a mixture of various kinds of tissue. They are derived from undifferentiated cells persisting from embryonic life. Adrenal or thyroid tissue may be present in it.
- Cysts may form in the ovary and may reach a very large size.
- The ovaries occupy the ovarian fossa only up to the time of the first pregnancy. After pregnancy, the broad ligament, to which the ovaries are anchored, becomes lax and the ovaries may descend and may even lie in the rectouterine pouch. Such a condition is called ***prolapse of the ovaries***. An ovary lying in the rectouterine pouch can be palpated on vaginal examination.

UTERINE TUBE

Other names: Fallopian tube (named after the 16th century Italian anatomist Gabriele Fallopius), oviduct, salpinx, tuba uterine.

The uterine tubes are a pair of ducts that transport the ovum released from the ovary to the uterus. Each uterine tube is about 10 cm long and lies in the medial three-fourth of the free margin of the corresponding broad ligament. It has medial and lateral ends. The ***medial end*** is attached to the corresponding side of the uterus where its lumen communicates with the uterine cavity. The ***lateral end*** of the tube lies near the ovary. At this end it has an opening through which its lumen is in communication with the peritoneal cavity. This opening is called the ***abdominal ostium***. The uterine tube undergoes a curved course to reach the ovaries because the combined length of the two tubes far exceeds the transverse diameter of the pelvic cavity. Each uterine tube first courses laterally, reaches the lower pole of the ovary, then passes upwards along the mesovarian border and then arches backwards around the tubal end of the ovary. Finally, it turns downwards and comes in contact with the posterior border and medial surface of the ovary.

Each uterine tube presents with four parts from the medial to lateral side (Fig. 24.4). These are the (a) intramural part (pars uterine tubae), (b) isthmus, (c) ampulla and (d) infundibulum.

The medial most part of the uterine tube which is embedded in the muscle wall of the uterus at the junction of the fundus and body of the uterus is the ***intra-mural part*** of the tube. It is 1 cm long.

The next 3 cm is thick-walled and has a narrow lumen so that it is cord like; this part is called the ***isthmus***.

The next 5 cm is thin walled and has a much larger lumen than the rest of the tube. This dilated part is called the ***ampulla***. Fertilisation of the ovum takes place in this part.

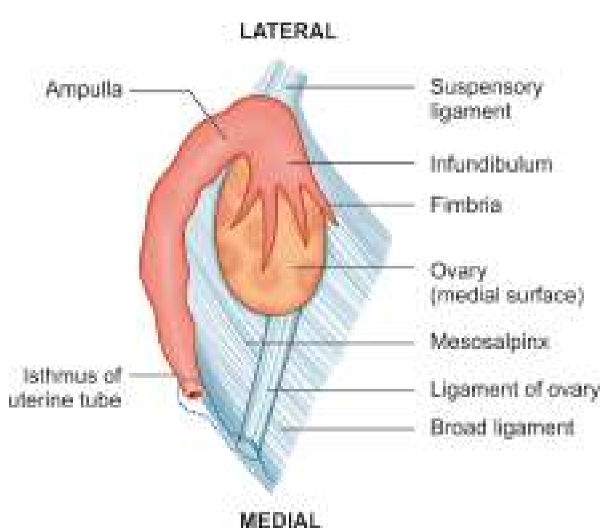


Fig. 24.4: Relationship of uterine tube to ovary as seen from the medial side

The lateral end of the uterine tube is funnel shaped and is called the ***infundibulum***. The wall of the infundibulum are prolonged into a number of irregular processes called the ***fimbriae***. One of the fimbriae is larger than the others and is in close contact with the ovary. It is called the ***ovarian fimbria***. The infundibular end presents with the abdominal ostium.

Ova discharged from the ovary enter the uterine tube through the infundibulum and pass into the ampulla. They slowly travel towards the uterus. The spermatozoa that enter the uterine tube through the vagina come in contact with the ovum in the ampulla of the tube. Fertilisation normally takes place in the ampulla. The fertilised ovum travels through the uterine tube towards the uterus to enter its cavity where it gets implanted in the uterine wall. The transport of ova is facilitated by the longitudinal grooves on the inner aspect of the ovarian fimbria, suction created by the ciliary beats of the uterine tubes and by the peristalsis of the tubal musculature. If fertilisation does not occur, the unfertilised ovum enters the uterus and is discharged through the vagina.

Histology

The uterine tube is composed of three layers from outside inwards—serous layer, muscular layer and mucous layer.

- The serous layer is derived from the peritoneum and covers the entire tube except the lower border and the intramural part.
- The muscular layer consists of the outer longitudinal and the inner circular layers of smooth muscle.
- The mucous layer is thrown into longitudinal folds and is lined by a single layer of tall ciliated columnar epithelium.

Apart from the ciliated columnar cells, secretory cells called the peg cells are also present. They are so called because they project further into the lumen than the ciliated columnar cells. The ciliated cells predominate in the distal part of the tube and the secretory cells in the proximal part. The secretions produced by the secretory cells provide nutrition to the gametes and aid in the capacitation of the spermatozoa. As said earlier, the cilia aid in the transport of the ova and the developing zygote.

Blood Supply

The medial two-thirds of each uterine tube are supplied by the corresponding uterine artery and its lateral one-third by the ovarian artery. The venous drainage corresponds to that of arteries.

Lymphatic Drainage

Lymph vessels travel along the ovarian vessels to the lateral aortic nodes. Intramural portion alone drains into the superficial inguinal lymph nodes along the round ligament of uterus.

Nerve Supply

The uterine tubes are supplied by both sympathetic and parasympathetic nerves. Parasympathetic innervation for the lateral half is from the vagus nerve along the ovarian artery and for medial half is from the pelvic splanchnic nerves along the uterine artery.

Sympathetic innervation is derived from the spinal segments T10 to L2. Visceral afferents mainly travel through the sympathetic nerves along the ovarian vessels and enter the spinal cord through its dorsal roots.

Clinical Correlation

- The uterine tubes may be absent or duplicated or may show atresia.
- Inflammation of the uterine tubes is called as ***salpingitis***. Salpingitis can lead to blockage of the tubes which may result in infertility. Genital tuberculosis commonly afflicts the tubes leading to infertility.
- The patency of the tubes can be tested by injecting a radio-opaque dye and visualising them in a radiograph. This procedure is called as ***hysterosalpingography***. The spillage of the injected dye can also be visualised by doing a diagnostic laparoscopy. Spillage of dye into the peritoneal cavity through the lateral end of the tube is an indication of patency of the tubes.
- The uterine tube is cut and ligated in a procedure called ***tubectomy***. It is the commonly followed procedure for permanent sterilisation in women (to prevent pregnancy).
- Sometimes the fertilised ovum may start developing within the ampulla of the uterine tube instead of reaching the uterus. This condition is called ***tubal pregnancy*** and is fatal if not diagnosed and managed early because as pregnancy advances the uterine tube can rupture leading to serious haemorrhage into the peritoneal cavity.

UTERUS

Other names: Womb, hystera.

The uterus is a thick walled hollow muscular organ situated obliquely within the lesser pelvis between the urinary bladder and rectum. It is mobile and its position varies with the distension of the bladder and rectum. The broad ligaments are lateral in position. On each side, the uterus receives the opening of the uterine tube at the superolateral angle and communicates below with the vagina through the external os of the cervix. It is primarily concerned with the implantation of the fertilised ovum and retaining the conceptus until term.

External Features

The uterus is piriform in shape and is about 7.5 cm (3 inches) in length. Its maximum width near its upper end is about 5 cm (2 inches) and its thickness is about 2.5 cm (1 inch).

The uterus is divided into two main regions. The body of the uterus (corpus uteri) forms the upper two-thirds, and the cervix (cervix uteri) forms the lower third. The site of demarcation between the body and the cervix is demarcated by a constriction at the junction of its upper two thirds with the lower one third. The part above the constriction is called the ***body***. The part below the constriction is called the ***cervix***.

Body of Uterus

The body of the uterus is pear shaped, i.e., broad above and narrow below and extends from the fundus superiorly to the cervix inferiorly. Near the upper end of the body of the uterus, the uterine tubes enter the uterus on both sides at the uterine cornua (lateral angles of the uterine body). The part of the body of the uterus that lies above the level of the openings of the uterine tubes is called the ***fundus***. The round ligament is attached to the uterus antero-inferior to the attachment of the uterine tube and the ovarian ligament posteroinferior to the uterine tube.

Sections across the uterus show that it has a thick wall, and a relatively narrow lumen. The wall is made up of a thick layer of muscle called the ***myometrium*** and of an inner lining of mucosa called the ***endometrium***. In a sagittal section through the uterus the lumen is seen as a narrow slit, the anterior and posterior walls being close to each other. In the coronal plane, the lumen of the body of the uterus is triangular. The lumen of each uterine tube joins the lateral angle of this triangle.

Cervix

The adult non-pregnant cervix is narrower and appears cylindrical. It measures about 2.5 cm in length. The cavity of the cervix (***cervical canal***) communicates above with the body of the uterus through the upper end called the ***internal os*** and below to the vagina through the lower end called the ***external os*** (Fig. 24.5). On both the anterior and posterior walls of the cervical canal, the mucosa shows a longitudinal ridge. Shorter folds arising from this ridge

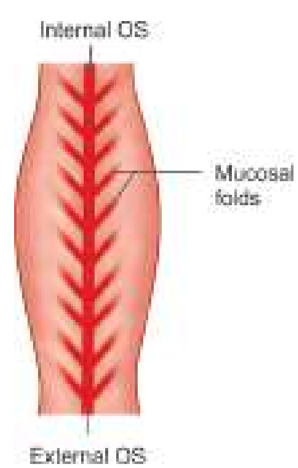


Fig. 24.5: Mucosal folds in the canal of the cervix

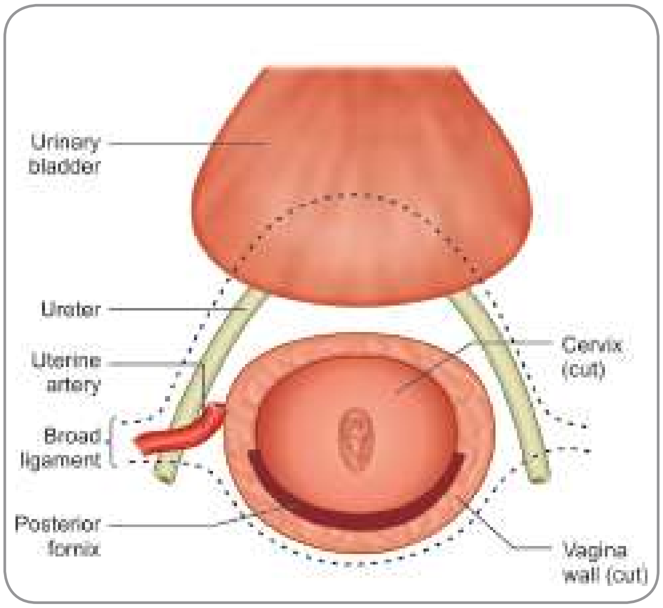


Fig. 24.6: Scheme to show the relationship of the ureters to the cervix of the uterus

pass upwards and laterally like branches from the stem of a tree. This pattern is referred to as the arbor vitae uteri (or plicae palmatae; Latin.arbour=tree) as the folds resemble the branching of a tree.

The upper one-third of the cervix is called the ***isthmus***. It shows cyclical menstrual changes as the uterine body but not so pronounced. During pregnancy, the isthmus is taken up by the lower part of the uterine body in the second month forming the lower uterine segment.

The external end of the cervix projects into the upper part of vagina, thereby dividing the cervix into supravaginal and vaginal parts. The lower end of the cervix is separated from the vaginal wall by recesses called the anterior, lateral, and posterior ***fornices*** (singular=fornix; Latin. Fornik=arch or vault) of the vagina. The posterior fornix is the deepest (Fig. 24.6).

Orientation of the Uterus

The uterus lies in the true pelvis. Its orientation is best appreciated in a sagittal section through the pelvis. In the erect posture, the long axis of the uterus is oblique. The fundus is directed forwards and somewhat upwards and the lower end is directed backwards and somewhat downwards. The long axis of the uterus is more or less at right angles to the long axis of the vagina. The forward bending of the cervix of the uterus relative to the vagina is referred to as ***anteversion*** of the uterus. The body of the uterus is also slightly bent forwards on itself relative to the cervix. This is referred to as ***anteflexion***.

Peritoneal relations to Uterus

The peritoneum from the anterior abdominal wall passes on to the superior surface of the urinary bladder. From the posterior part of this surface the peritoneum is reflected on to the 'anterior' (actually anteroinferior) surface of the uterus at the junction of the body with the cervix. It lines the 'anterior' surface of the body, passes over the fundus and runs over the 'posterior' (actually postero-superior) aspect of the uterus reaching the upper part of the vagina from where it is reflected on to the front of the rectum. The peritoneum lined space between the front of the body of the uterus and the superior surface of the urinary bladder is called the ***vesicouterine pouch***. The space between the uterus and the uppermost part of the vagina in front, and the rectum behind is called the ***rectouterine pouch*** (or ***pouch of Douglas***). The pouch is really rectovaginal. It is important to know that the bottom of the pouch is only about 5 cm from the anal orifice. When traced laterally the layers of peritoneum lining the front and back of the uterus meet along its lateral margins to form the broad ligament.

Relations of Uterus

The ***anterior*** surface of the uterus is related to the superior surface of the urinary bladder. The body of the uterus is separated from the bladder by peritoneum, but the upper part of the cervix is in direct contact. The ***posterior*** surface of the uterus (both body and cervix) is separated by peritoneum from the sigmoid colon and from coils of small intestine.

On either side of the uterus, the corresponding uterine artery reaches the lateral side of the cervix and then ascends along the lateral margin of the body of the uterus, lying between the two layers of peritoneum forming the broad ligament. The ureters run downwards and forwards for a short distance of about 2 cm lateral to the cervix.

Ligaments of Uterus (Fig. 24.7)

The uterus is attached to surrounding structures through a number of ligaments. Some are true ligaments as they

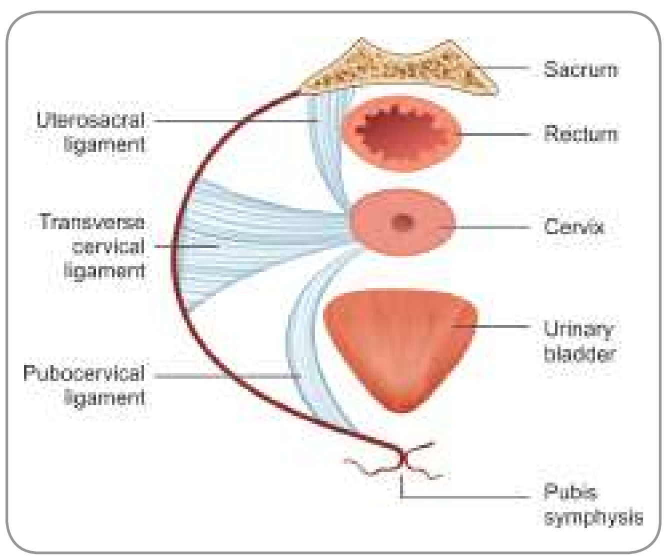


Fig. 24.7: Scheme to show ligaments of uterus

are made up of fibrous tissue and provide support to the uterus; others provide no support to the uterus and are mere folds of peritoneum (false ligaments).

Fibrous Ligaments (True Ligaments)

The ***transverse cervical ligament*** (also called the ***lateral, cardinal*** or ***Mackenrodt's ligament*** or ***the cervical ligament of uterus***) passes from the lateral side of the cervix (and the upper end of the vagina) to the lateral wall of the pelvis. The uterine vessels are embedded in it.

- The ***pubocervical ligaments*** extend between the anterior aspect of the cervix and the posterior aspect of the pubic bones.
- The ***uterosacral ligaments*** connect the uterus to the sacrum. They lie within the rectouterine peritoneal folds.
- The ***round ligament*** (or the ligamentum teres uteri) of the uterus is 10 to 12 cm long. It is attached to the upper lateral part of the body of the uterus, just below and in front of the uterine tube and lies within the broad ligament. It further runs forwards across the lateral wall of the pelvis and crosses the external iliac vessels, where it hooks around the lateral side of the inferior epigastric artery and enters the deep inguinal ring. It then passes through the inguinal canal and after emerging from the superficial inguinal ring, it ends in the connective tissue of the labium majus.

Folds of Peritoneum (False Ligaments)

The fold of peritoneum reflected from the anterior aspect of the uterus to the urinary bladder is called the uterovesical fold (***anterior ligament).***

- The fold of peritoneum reflected from the posterior aspect of uterus and the upper part of vagina to the rectum is called the rectovaginal fold (***posterior ligament)***. It forms the floor of the rectouterine pouch.
- Two folds (right and left) pass from the side of the cervix to the rectum and posterior wall of the pelvis. These are called the ***rectouterine folds***. These folds form the lateral boundaries of the rectouterine pouch.
- The folds of peritoneum reflected laterally from the sides of the uterus to the lateral wall and floor of the pelvis are called the ***broad ligaments***.

Boundaries of Rectouterine Pouch

The rectouterine pouch of Douglas is the most dependent part of the pelvic peritoneal cavity in females. It is bounded by:

- ***Anteriorly:*** Supravaginal part of cervix and posterior fornix of vagina;
- ***Posteriorly:*** Middle one-third of rectum;
- ***Laterally:*** Rectouterine fold;
- ***Floor:*** Rectovaginal fold, which lies 5.5 cm above the anus and 7.5 cm above the external orifice of anus.

Broad Ligament

The broad ligament along with the uterus forms a transverse partition which divides the pelvic cavity into an anterior compartment for the bladder and a posterior compartment for the sigmoid colon and rectum. It is quadrilateral in outline and presents anteroinferior and posterosuperior surfaces, and four borders. The anteroinferior surface is related to the upper surface of the bladder. The posterosuperior surface gives attachment to the ovary by a fold of peritoneum called the ***mesovarium***. The upper border is free and contains the uterine tube in the medial three-fourth and suspensory ligament of ovary in the lateral one-fourth. The lower border is attached to the pelvic floor and the ureter and uterine artery enter below this border. The medial border is attached to the lateral wall of the uterus and the lateral border to the lateral pelvic wall.

Contents of Broad Ligament

- The uterine tube except the intramural part;
- The proximal part of the round ligament of the uterus below and in front of the tube;
- The ligament of the ovary below and behind the tube;
- The ovarian vessels in the suspensory ligament;
- The uterine vessels which enter through the base of the broad ligament and anastomose with the ovarian vessels near the lateral angle of the uterus;
- Tubules and duct of epoophoron (Duct of Gartner)—the tubules are remnants of the proximal mesonephric tubules and the duct is a remnant of the cephalic part of the mesonephric duct;
- Tubules of paroophoron which are remnants of distal mesonephric tubules;
- Lymphatics, nerves and unstriped muscles of uterus;
- Occasionally, accessory suprarenal tissue.

The broad ligament is divided into the mesosalpinx, mesovarium and mesometrium. ***Mesosalpinx*** extends between the uterine tube and the mesovarium of the ovary. ***Mesovarium*** is that part of peritoneal fold which extends from the ovary to the broad ligament. ***Mesometrium*** is the largest part and extends from the pelvic floor to the uterine body and ovarian ligament.

Supports of Uterus

The angulation between the body of the uterus and cervix, and that of the cervix and vagina depend on the condition of the bladder and rectum. The uterus is normally maintained in the anteverted and anteflexed position when the bladder is empty. When the bladder distends, the uterus gradually straightens and lies in the same line with vagina. This position favours a descent of uterus especially when the intra abdominal pressure is increased. However, this descent is prevented by the supports of uterus.

The supports of uterus can be broadly divided into primary supports and secondary supports.

Primary Supports

The primary supports can further be subclassified into muscular, visceral and fibromuscular (ligamentous) supports.

Muscular Supports

- The levator ani muscles of the pelvic diaphragm and the pelvic fascia lining them form the main muscular support to the uterus. The pubovaginalis part directly assists in the uterine support by constricting the hiatus urogenitalis, thereby preventing the descent of uterus. The puborectalis part assists in the uterine support indirectly. It maintains the ano-rectal flexure on which the posterior vaginal wall rests. The posterior vaginal wall in turn supports the tip of the cervix of an anteverted uterus. If the puborectalis is damaged, the anorectal flexure is lost, which causes the posterior vaginal wall to straighten, thereby causing the cervix and associated uterus to descend.
- The perineal body is the other muscular support to the uterus. It is a pyramidal shaped fibromuscular node which intervenes between the vaginal and anal orifices. It receives the attachment of various pelvic muscles and assists in maintaining the integrity of the pelvic floor. It is also called the ***gynaecological perineum***.
- Muscles of urogenital diaphragm, deep transverse perineal and sphincter urethrae muscles and fascia over their superficial surface also contribute to the muscular supports of uterus.

Fibromuscular (Ligamentous) Supports

The transverse cervical, pubocervical, uterosacral and the round ligaments of uterus provide this support.

Visceral Supports

- The slanting posterior wall of the vagina supports the uterine load in ***anteverted position***.
- The anorectal flexure supports the obliquity of the posterior vaginal wall.
- The upper surface of the bladder acts as a support on which the body of the uterus rests in normal anteverted position.
- The pressure of the sigmoid colon and small intestine assists anteversion by maintaining pressure on the uterus and keeping it in anteverted position.

Secondary Supports

Additional support is provided by the peritoneal folds described above which are the broad ligament, uterovesical and rectovaginal folds of peritoneum.

Variability in Size, Shape and Position of Uterus

At the time of birth, the cervix of the uterus is large and the body is small. Thereafter, the body grows more than the cervix so that by puberty the uterus acquires its normal piriform shape.

At the time of menstruation, the uterus undergoes slight enlargement.

During pregnancy, it undergoes great enlargement, when its upper end reaches the epigastrium. After the delivery, the uterus gradually approaches near its normal size by 6 weeks but the size of its cavity and the thickness of its muscle wall remain larger than they were before pregnancy. The external os also becomes more prominent.

The uterus undergoes atrophy in old age.

Blood Supply

The uterus is mainly supplied by the uterine arteries and partly by ovarian arteries. The uterine artery is a branch of anterior division of internal iliac artery. It runs medially across the pelvic floor in the base of the broad ligament, towards the uterine cervix. It crosses the ureter from above lateral to the cervix and then ascends along the lateral border of the uterus (the relation of the artery and ureter lateral to the cervix is usually remembered as ***"water under the bridge"*** with the water depicting the ureter containing urine and the bridge represented by the uterine artery). At the lateral angle of the uterus (cornua), the uterine artery turns laterally and ends by anastomosing with the ovarian artery at the junction of the middle and lateral one-third of the uterine tube. The main trunk of the uterine artery and many of its branches show marked tortuosity.

The uterine artery gives branches to the cervix, ureter, vagina, Fallopian tube and a few twigs to the ovary. Along the lateral border of the uterus, it gives off the arcuate (coronary) branches to the uterus, which run transversely on the anterior and posterior surfaces of the body of uterus and anastomose with their fellows of the opposite side in the midline.

Added Information

Uterine circulation: The arcuate arteries give rise to radial arteries which pierce the myometrium and anastomose with each other to form the stratum vasculare in the middle layer of myometrium. Two sets of branches called the basal arteries and spiral arteries arise from the vasculare stratum to supply the endometrium. The basal arteries supply the basal zone of the endometrium and spiral arteries supply the functional zone. The contraction of the spiral arteries leads to menstruation. The functional zone is cast off in menstruation and the basal arteries help in the regeneration of the functional endometrium following menstruation. During parturition, after the expulsion of the placenta, the myometrium contracts, thereby constricting the stratum vasculare layer. This results in significant arrest of post-partum bleeding. Hence the middle layer of myometrium consisting the stratum vasculare is also called the living ligature of uterus.

The uterine veins follow the arteries and drain into the internal iliac veins.

Lymphatic Drainage

Lymphatic drainage of the uterus is through three intercommunicating plexuses, namely the submucous, intramuscular and subserous plexuses. The collecting ducts of these plexuses pass laterally in the parametrium. Collecting ducts from the fundus and upper part of the body of uterus drain into the preaortic and lateral aortic nodes. A few vessels from the lateral angles run along the round ligament of uterus and drain into the superficial inguinal lymph nodes. Lymphatics from the lower part of the body of the uterus drain into external iliac lymph nodes.

The lymph vessels from cervix drain laterally into the external iliac and internal iliac lymph nodes and posteriorly into the sacral nodes.

Nerve Supply

The uterus is supplied by autonomic nerves, both sympathetic and parasympathetic. The nerves reach the uterus through the hypogastric plexuses and the ovarian plexus present along the ovarian artery. The sympathetic fibres are derived from spinal segments T12 to L1. The parasympathetic fibres are derived from the sacral outflow (S2,3,4). The sympathetic stimulation causes uterine contraction and vasoconstriction. The parasympathetic stimulation causes relaxation of uterus and vasodilatation. However, the uterus is more under hormonal control than nervous control. The pain fibres from the uterine body are carried by the sympathetic fibres and those of the cervix are carried by the parasympathetic fibres.

Histology

The uterus is made up of three layers. From outside inwards, they are the serous layer (layer of the covering peritoneum), muscular layer (called the myometrium) and mucosal layer (called the endometrium).

The muscle layer of the uterus is called the ***myometrium***. It consists of bundles of smooth muscles with some amount of connective tissue. Numerous blood vessels, nerves and lymphatics are also present. The myometrium is arranged in three layers—external (longitudinal layer), middle and internal (longitudinal). The muscle fibres in the middle layer are arranged in reticular; this layer when it contracts after delivery causes the blood vessels in them also to contract, thereby arresting blood loss.

The mucous membrane of the uterus is called the ***endometrium***. The endometrium consists of a lining epithelium which rests on a stroma. Numerous uterine glands are present in the stroma. The epithelium is lined by simple columnar cells. Before the onset of menarche, the columnar cells are ciliated but with repeated menstruation and periodic denuding of the functional layer, cilia is lost in the adult endometrium. The endometrium changes according to the phase of the menstrual cycle. In proliferative phase, the epithelial cells proliferate and are thicker. In secretory phase, in addition to the thick epithelial layer, the uterine glands in the stroma become bigger and saw toothed.

contd…

Histology *contd…*

The cervix consists of predominantly fibroelastic tissue and less of smooth muscle. The elastin component is essential for the stretching of the cervix during parturition. The mucous membrane is lined by simple columnar epithelium in the upper two-third. At the level of the external os, it is lined by non keratinised stratified squamous epithelium. The mucous membrane has a number of obliquely placed palmate folds. It contains numerous branching glands which secrete mucus. Sometimes, the ducts of the glands are blocked and the secreted mucus accumulates; dilatation of the ducts and glands lead the formation of cysts called the Nabothian cysts (named after the 17th century Leipzig anatomist Martin Naboth).

Clinical Correlation

- ***Congenital anomalies:*** The uterus may be duplicated, may be divided by a septum, or may be absent. Only one half of the uterus (and one uterine tube) may be present ***(unicornuate uterus)***. Sometimes the cervix is absent. There may be atresia of the lumen. The uterus may remain rudimentary.
- Weakening of the pelvic diaphragm can lead to ***prolapse*** of uterus. Retroversion also predisposes to prolapse (as the uterus comes in line with the vagina).
- Neoplasms may occur in the uterus; these may be benign or malignant. The most common growth is a fibroma (fibroid) which can be multiple. It is benign in nature. Carcinoma is more common in the cervix.
- The most common surgical procedures performed on the uterus is a ***caesarean section.*** It is done in cases where normal birth of a baby is not possible and delivery is done by opening the uterus.
- Surgery for opening of the uterus is called ***hysterotomy*** and removal of the uterus is called ***hysterectomy***.
- Instruments may be passed into the uterus after dilating the cervix for termination of pregnancy, or for curetting (scraping) of the endometrium to study the pathology.
- Intrauterine contraceptive devices (IUCD) made of metal or plastic may be inserted into the uterus to prevent implantation of a fertilised ovum, which is one of the common methods followed for temporary sterilisation.

VAGINA

Other name: colpos.

The vagina (Latin.vagina=sheath; Greek.colpos=hollow) is a tubular structure with a muscular wall. Its lower end opens to the exterior through the vestibule. At its upper end it is attached to the cervix of the uterus. The cervix projects into the upper part of the vagina through the uppermost part of its anterior wall. The space between the cervix and the adjoining parts of the vaginal wall is divided into the anterior, posterior and lateral fornices. The long axis of the vagina runs upwards and backwards and is approximately at right angles to that of the uterus.

The vagina has anterior and posterior walls. The anterior wall is shorter than the posterior. The anterior wall is about 7.5 cm long and the posterior wall about 9 cm long. The anterior wall of the vagina is related above to the base of the urinary bladder, and below to the urethra. The relationship with the urethra is intimate, the latter being embedded in the vaginal wall. The posterior wall of the vagina is related from above downwards to the rectouterine pouch, rectum and the perineal body. The perineal body separates the vagina from the anal canal. Laterally, the vagina is related to the levator ani muscles, and at its upper end to the uterine arteries and the ureters.

Blood Supply

The vagina is supplied mainly by the vaginal branch of the internal iliac artery. It also receives branches from the uterine, internal pudendal and middle rectal arteries.

The vaginal veins end in the internal iliac veins.

Lymphatic Drainage

The lymphatic drainage of the vagina is as follows:

- Lymph vessels from the upper part of the vagina travel along the uterine artery to the internal and external iliac nodes.
- Those from the middle of the vagina run along the vaginal artery to reach the internal iliac nodes.
- The lower part of the vagina drains into the superficial inguinal nodes.

Nerve Supply

The vagina receives autonomic nerves which reach it along the vaginal arteries. The lower part of the vagina receives sensory branches from the pudendal nerves through their inferior rectal and posterior labial branches.

Clinical Correlation

- ***Congenital anomalies:*** The vagina may be duplicated, may be subdivided by a septum, or may be absent. The hymen may be imperforate. Abnormal communications may exist with the rectum (**rectovaginal fistula**) or with the urinary bladder (**vesicovaginal fistula**).
- ***Vaginal examination:*** Most of the structures related to the vagina can be palpated through fingers introduced into the vagina. On the anterior side, the pubic symphysis, urinary bladder and the urethra are felt. Posteriorly, the rectum and any structure lying in the rectouterine pouch may be felt. The perineal body can also be felt. On either side, the structures that can be felt through the vaginal wall are the ovary, the uterine tube, the ureter, and the urogenital diaphragm. The position and size of the uterus can be determined.
- ***Colposcopy:*** The cervix can also be visualised for macroscopic changes through the vagina by a procedue called ***colposcopy***.

  Colposcope is an endoscopic instrument, which when introduced into the vagina will magnify the cells of the vagina and cervix thus permitting direct examination of these structures.
- Prolapse of the uterus is accompanied by some degree of prolapse of the vagina. There can be ***prolapse of the vagina*** without prolapse of the uterus. The urinary bladder may bulge into the vagina through the weakened anterior wall (***cystocoele***). The rectum also may bulge through the posterior wall (***rectocoele***).
- The vaginal wall can be weakened by pressure of the foetal head. Trauma during childbirth can lead to the formation of a fistula between the vagina and the rectum.
- Surgical procedures on the vagina include ***colpotomy*** or repair of the wall (***colporrhaphy***).
- Injury to the vagina can be caused by carelessly introduced instruments. Perforation of the posterior fornix in this way can lead to peritonitis and death.

Multiple Choice Questions

1. The ovarian artery is a branch of:
   a. Abdominal aorta
   b. Uterine artery
   c. Renal artery
   d. Superior mesenteric artery

2. The lateral end of the Fallopian tube forms the:
   a. Isthmus
   b. Pars intramurale
   c. Infundibulum
   d. Ampulla

3. The pouch of Douglas is bounded laterally by the:
   a. Recto-uterine folds
   b. Recto-vaginal fold
   c. Broad ligaments
   d. Utero-vesical folds

4. Living ligature of uterus is:
   a. Middle layer of myometrium
   b. Broad ligament
   c. Levator ani
   d. Position of anteversion

5. Nabothian cysts are blocked accumulations of:
   a. Cervical mucous glands
   b. Uterine stromal glands
   c. Spiral arteries
   d. Ovarian tubules

ANSWERS

1. a **2.** c **3.** a **4.** a **5.** a

Clinical Problem-solving

Case Study 1: A 35-year-old woman is diagnosed to have uterine fibroids.

- What is a fibroid?
- Enumerate some surgical procedures done on the uterus.
- What is the difference between hysterotomy and hysterectomy?

Case Study 2: A 67-year-old woman has prolapse of uterus.

- What is your understanding of the condition?
- What is cystocoele?
- If the rectum has a similar fate, what is it called?

(For solutions see Appendix).

Chapter 25

Lymphatics and Autonomic Nerves of Abdomen and Pelvis

Frequently Asked Questions

- Write notes on: (a) Pre-aortic lymph nodes, (b) Lymphatic drainage of stomach, (c) Lymphatic drainage of urinary bladder.
- Write notes on: (a) Lymphatic drainage of liver, (b) Lymphatic drainage of jejunum and ileum, (c) Lymphatic drainage of large intestine.
- Write briefly on: (a) Lymphatic drainage of uterus and uterine tube, (b) Lymphatic drainage of pancreas, (c) Autonomic plexus and ganglia.

LYMPHATICS OF ABDOMEN AND PELVIS

The largest lymph vessel in the body is the ***thoracic duct***. It begins in the abdomen as an upward continuation of a sac-like structure called the ***cisterna chyli*** (Fig. 25.1). Most of the lymph from the abdomen drains into the cisterna chyli and from there into the thoracic duct, which finally drains into the venous system. The thoracic duct has been discussed in the section on thorax.

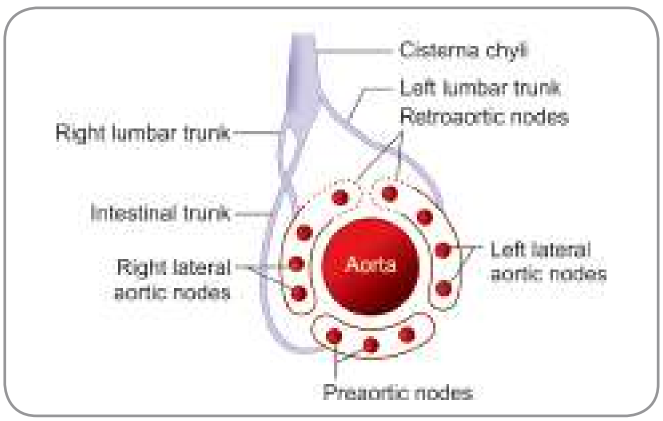


Fig. 25.1: Scheme to show the terminal lymph nodes of the abdomen

CHIEF LYMPH NODES OF ABDOMEN AND PELVIS

The lymph from most of the abdominal wall and from all the abdominal viscera (except a small part of the liver) drains into the lymph nodes which are placed along the arteries related to the concerned structures or viscera. These lymph nodes are the outlying groups of nodes. The outlying groups, in turn, drain into the terminal groups of lymph nodes present in relation to the abdominal aorta. The terminal nodes are called the ***lumbar lymph nodes*** and are arranged in three main groups, each having a specific area of drainage. The three groups of lymph nodes are the preaortic nodes, lateral aortic nodes and the retroaortic nodes.

- The preaortic nodes are located in front of the aorta and drain the viscera supplied by the ventral branches of aorta. They are further subdivided into three groups corresponding to the origin of the three ventral branches of aorta, namely the coeliac, superior mesenteric and the inferior mesenteric nodes (Fig. 25.2). Efferents from all the preaortic nodes form the intestinal trunk which ends in the cisterna chyli.
- The right and left lateral aortic nodes are situated on either side of the aorta and drain the viscera and other structures supplied by the lateral and dorsal branches of aorta (Fig. 25.3). They receive afferents from the large lymph nodes along the iliac arteries. The efferents from the lateral aortic nodes form the corresponding lumbar trunks which end by joining the cisterna chyli (Fig. 25.1).
- Some outlying members of the lateral aortic nodes lying behind the aorta constitute the retroaortic nodes. They do not have a separate drainage area, though they may be primarily associated with drainage of the posterior abdominal wall.

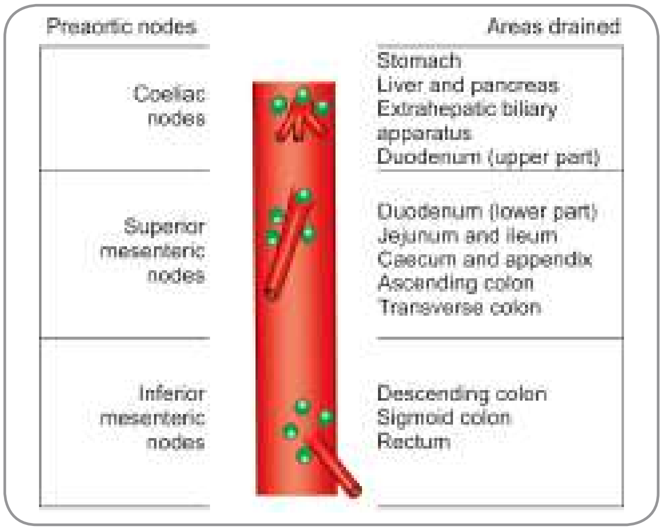


Fig. 25.2: Subgroups of the preaortic lymph nodes, and areas drained by them

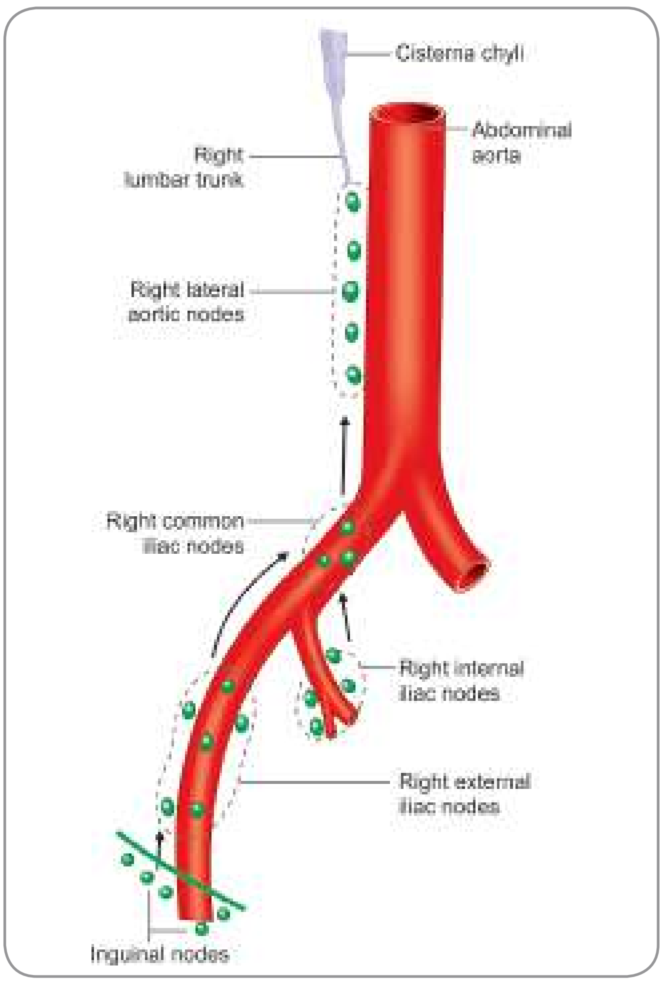


Fig. 25.3: The lateral aortic lymph nodes

Preaortic Lymph nodes

- The ***coeliac lymph nodes*** receive lymph from the organs/structures developed from the foregut, namely:
  - Stomach,
  - Most of duodenum,
  - Liver,
  - Extrahepatic biliary apparatus,
  - Pancreas, and
  - Spleen

  The coeliac lymph nodes receive their afferents through the lymph nodes lying along the branches of the coeliac artery which are the ***gastric***, ***hepatic*** and ***pancreaticosplenic*** nodes.
- The ***superior mesenteric lymph nodes*** receive lymph from the organs/structures developed from the midgut, namely:
  - Part of duodenum,
  - Jejunum,
  - Ileum,
  - Caecum,
  - Appendix,
  - Ascending colon, and
  - Part of transverse colon
- The ***inferior mesenteric lymph nodes*** receive lymph from the organs/structures developed from the hind gut, namely the:
  - Part of transverse colon,
  - Descending colon,
  - Sigmoid colon, and
  - Upper part of rectum

The area of drainage of the preaortic nodes is shown in figure 25.2

The ***lateral aortic nodes*** (Fig. 25.3) drain lymph from the common iliac nodes. They also receive lymph directly from the posterior abdominal wall, kidneys and upper part of ureters, testes or ovaries, uterine tubes and part of the uterus.

The ***common iliac nodes*** (Fig. 25.3) lie along the corresponding blood vessels. They receive lymph from the external and internal iliac nodes and drain into the lateral aortic nodes. The ***internal iliac nodes*** (Fig. 25.3) lie along the corresponding blood vessels. They receive most of the lymph of the pelvic organs and from the deeper tissues of the perineum. They also receive some vessels of the lower limbs that travel along the superior and inferior gluteal blood vessels. The ***external iliac lymph nodes*** (Fig. 25.3) lie along the external iliac blood vessels. They receive lymph from the lower limb through the inguinal nodes. They also receive lymph vessels directly from the deeper tissues of the infraumbilical part of the anterior abdominal wall and from some pelvic organs.

LYMPHATIC DRAINAGE OF ABDOMINAL AND PELVIC VISCERA

Lymphatic Drainage of Stomach

The stomach is divided into four regions for the purpose of lymphatic drainage. The fundus and left half of body of stomach (area A) drain into the pancreatico splenic

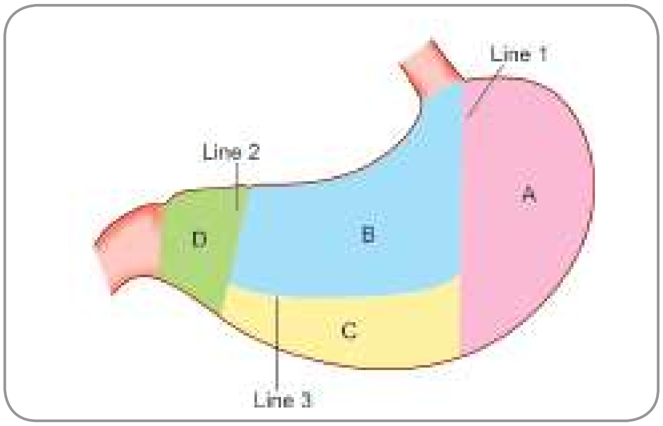


Fig. 25.4: Areas of stomach having separate lymphatic drainage

nodes. The upper right half of body of stomach (area B) drains into the left gastric nodes. The lower right half of body of stomach (area C) drains into the right gastro epiploic nodes which in turn drain into the pyloric nodes which lie in the angle between the first and second parts of duodenum. Efferents from the pyloric nodes drain into the hepatic nodes which lie along the hepatic artery. The pylorus of the stomach (area D) drains into pyloric nodes, which then drain into the hepatic nodes. The lymphatics from these nodes reach the coeliac nodes ultimately (Fig. 25.5).

Subdivisions of stomach for the purpose of lymphatic drainage: A vertical line is drawn immediately to the left of the cardio-oesophageal junction. The part to the left of this line is area A. Another vertical line is drawn separating the pyloric part of the stomach (Area D) from the body. The area between these two vertical lines is divided into two unequal parts by a curved line drawn parallel to the greater curvature so that the area above it (Area B) is larger (2/3rd) than the area (C) below it (Fig. 25.4).

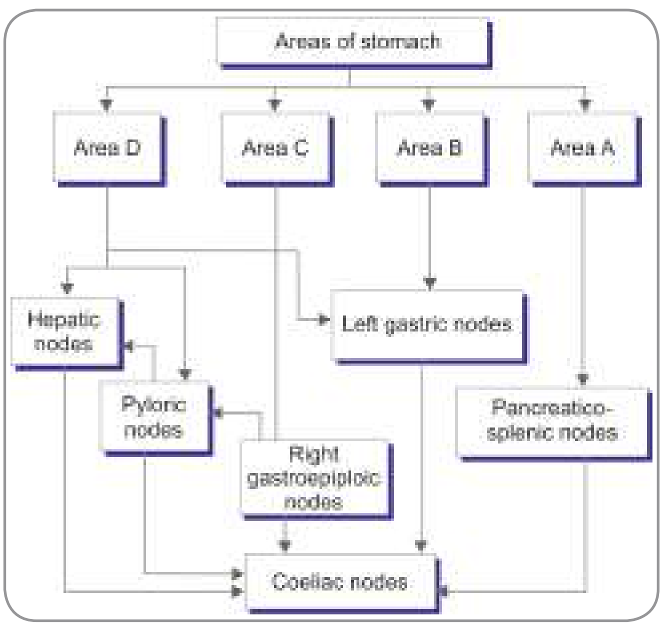


Fig. 25.5: Scheme to show the lymphatic drainage of stomach

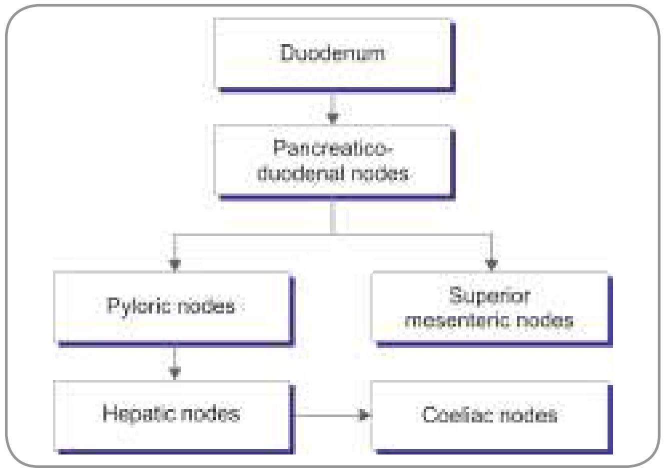


Fig. 25.6: Scheme to show the lymphatic drainage of duodenum

Lymphatic Drainage of Duodenum

The lymph from the duodenum drains into the pancreaticoduodenal nodes, present along the inside of the curve of the duodenum (i.e., at the junction of the pancreas and the duodenum) (Fig. 25.6). From here lymph passes to the hepatic, coeliac and superior mesenteric nodes.

Some vessels from the first part of the duodenum drain into the pyloric nodes, and through them to the hepatic nodes. Some vessels drain into the hepatic nodes directly. All the lymph reaching the hepatic nodes drains into the coeliac nodes.

Lymphatic Drainage of Jejunum and Ileum

The lymphatic drainage of the jejunum is through nodes present in the mesentery along branches of the superior mesenteric artery. Ultimate drainage is into the superior mesenteric nodes. The lymphatic drainage of the ileum is through nodes present in the mesentery along branches of the superior mesenteric artery and the ileocolic artery, which drain into superior mesenteric nodes.

The lymphatic drainage of the small intestine deserves special attention as it is rich and dense. Food substances, especially fats, are absorbed through them.

- The mucous membrane of the small intestine is studded with finger like processes called ***villi***. Each villus has a central lymph vessel called the ***lacteal*** (Fig. 25.7). Lymph from the lacteals drains into plexuses in the wall of the gut and from there to vessels in the mesentery (Fig. 25.8). It ultimately reaches lymph nodes present in front of the aorta at the origin of the superior mesenteric artery.
- Before reaching these nodes, the lymph from the intestines passes through hundreds of lymph nodes located in the mesentery. These nodes are present near the mesenteric border of the gut, along the branches of the superior mesenteric artery including the arcades

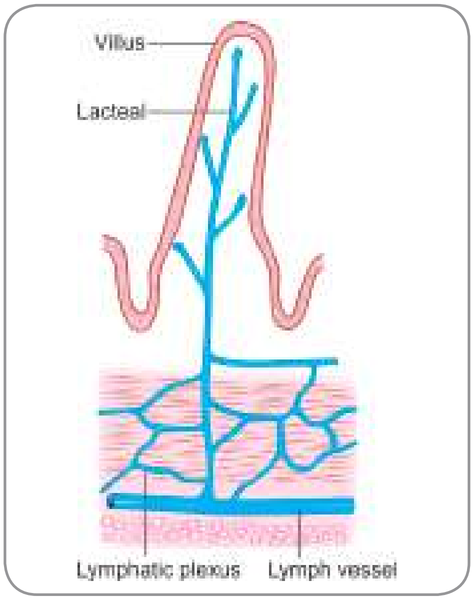


Fig. 25.7: Scheme to show arrangement of lymph vessels within the gut

and along the trunk of the superior mesenteric artery itself.

Lymphatic Drainage of Caecum and Appendix

Lymph from the caecum and appendix drains into the superior mesenteric lymph nodes after passing through the several outlying nodes, especially the ileocolic nodes. The outlying nodes are present along the ileocolic artery and its anterior caecal, posterior caecal and appendicular branches (***anterior ileocolic nodes, posterior ileocolic nodes*** and ***appendicular nodes*** respectively) (Fig. 25.8).

Lymphatic Drainage of Colon

The lymph from the ascending colon and right two-thirds of transverse colon drain into the superior mesenteric nodes and those from the left one-third of transverse colon and descending colon drain into the inferior mesenteric nodes.

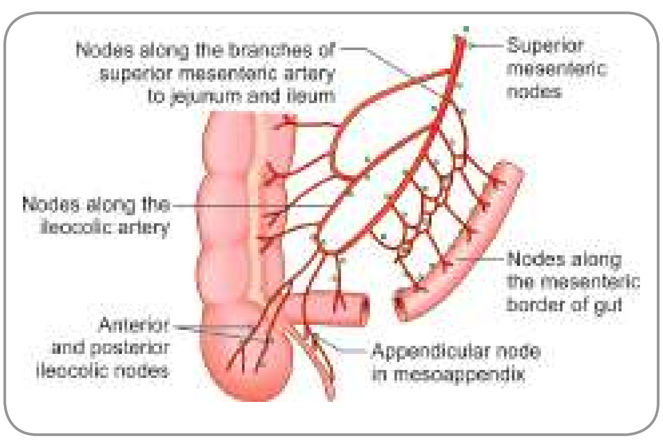


Fig. 25.8: Lymph nodes draining the jejunum, ileum, caecum and appendix

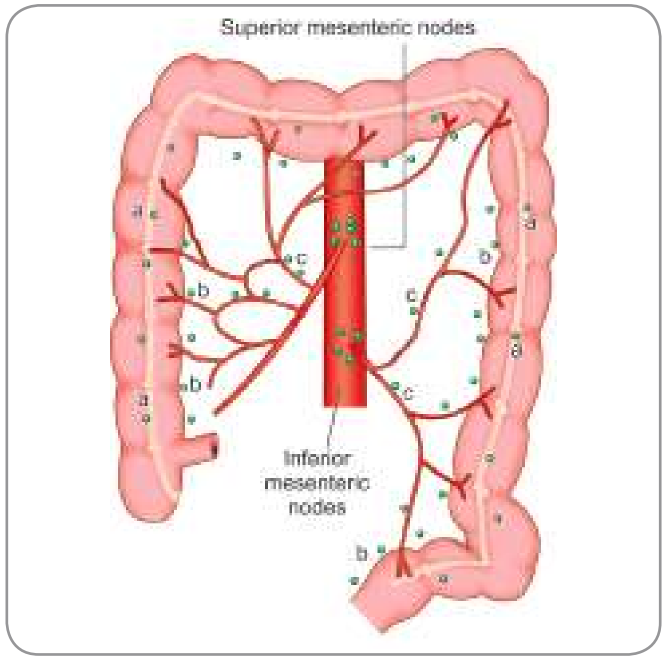


Fig. 25.9: Lymph nodes draining the colon
Key: a. Epicolic nodes **b.** Paracolic nodes **c.** Nodes along colic branches

On its way to these groups,lymph passes through outlying nodes which lie (Fig. 25.9) on the wall of the colon itself (called the ***epicolic nodes***), along the 'inner' border of the colon (called the ***paracolic nodes***) and along the right and middle colic branches of the superior mesenteric artery and the left colic branch of the inferior mesenteric artery.

Lymphatic Drainage of Rectum and Anal Canal

The upper part of the rectum drains into the inferior mesenteric nodes through lymph vessels passing along with the superior rectal artery and inferior mesenteric artery (Fig. 25.10). The lower part of the rectum and the upper part of the anal canal drain into the internal iliac nodes through lymph vessels running along with the middle rectal artery.

The lower part of the anal canal drains into the superficial inguinal nodes.

Lymphatic Drainage of Liver

The lymphatic drainage of the liver is into the nodes around the upper end of inferior vena cava, nodes in the porta hepatis and the coeliac nodes. The liver is drained by two sets of lymphatics—the superficial and the deep.

The superficial lymphatics form a network in the subperitoneal fibrous capsule of the liver called the ***Glisson's capsule***. They drain into the pericaval nodes, hepatic nodes, coeliac nodes, paracardiac nodes and the phrenic nodes.

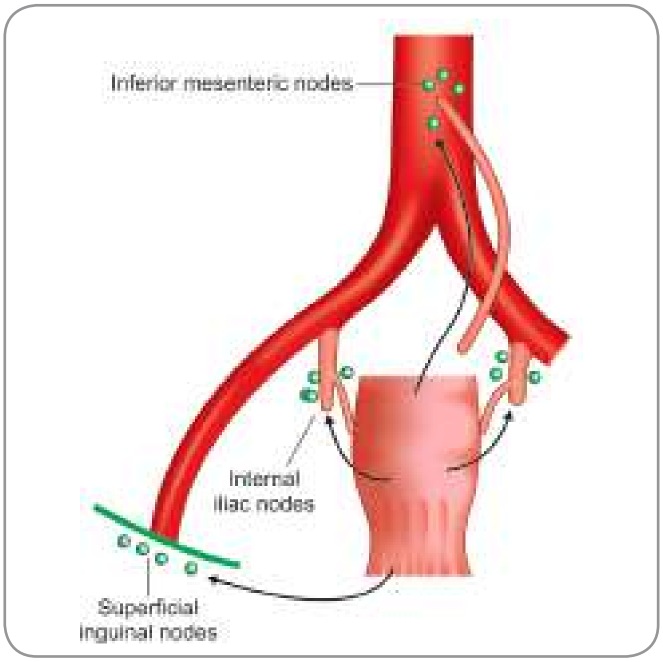


Fig. 25.10: Scheme to show the lymphatic drainage of rectum and anal canal

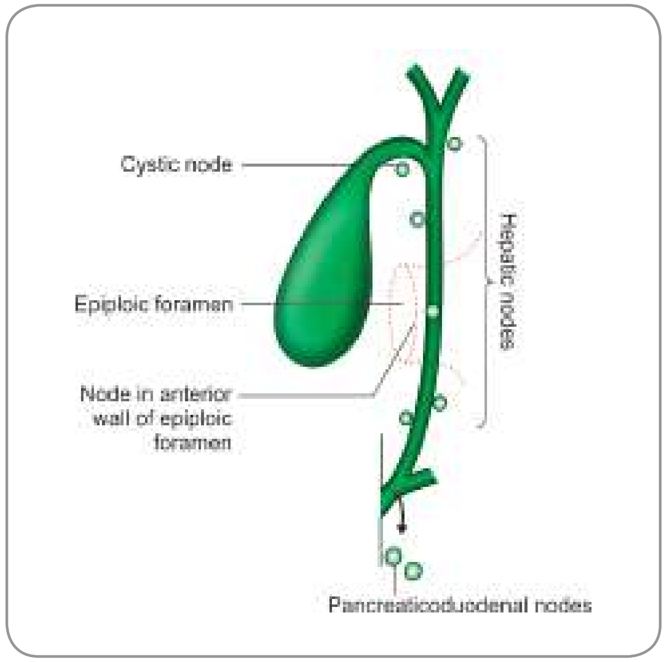


Fig. 25.12: Lymphatic drainage of gallbladder and bile duct

The deep lymphatics accompany the portal triads and the ramifications of the hepatic veins. They join to form the ascending and descending trunks. The ascending trunks accompany the hepatic veins and drain into the nodes around the inferior vena cava ('a' and 'd' in Fig. 25.11). The descending trunks emerge out of the porta hepatis ('e' in Fig. 25.11) and drain into the hepatic lymph nodes ('b' in Fig. 25.11). The efferents from the hepatic nodes pass to the coeliac nodes ('c' in Fig. 25.11) which, in turn, drain into the cistern chyli.

Lymphatic Drainage of Gallbladder and Bile Duct

Lymphatics from the gallbladder and the bile duct drain into the hepatic nodes (including the cystic node) and through them to the coeliac nodes (Fig. 25.12). Two of the hepatic nodes are specially important. One of them, the ***cystic node***, lies near the neck of the gallbladder. Another node lies in the anterior wall of the epiploic foramen. Lymph vessels from the lower end of the bile duct may directly drain into the pancreaticoduodenal nodes.

Lymphatic Drainage of Pancreas

Lymphatics of the pancreas drain into the pancreaticosplenic nodes along the splenic artery and to the pancreatico-duodenal nodes lying at the junction of pancreas and duodenum (both anteriorly and posteriorly) (Fig. 25.13). The efferents from these nodes reach the coeliac nodes. Some lymph vessels may reach the superior mesenteric nodes.

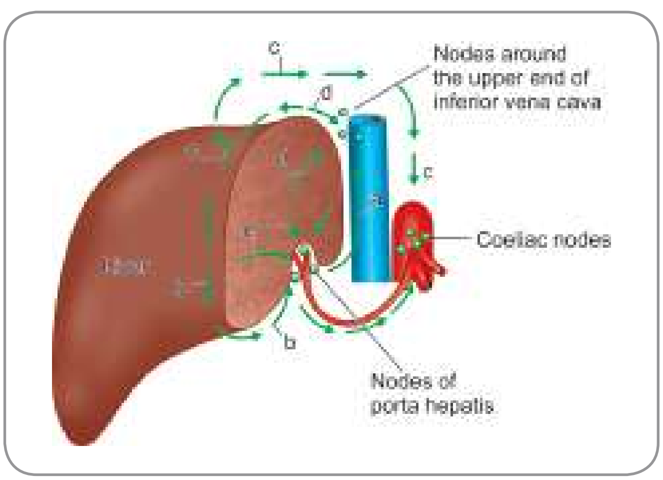


Fig. 25.11: Lymphatic drainage of liver

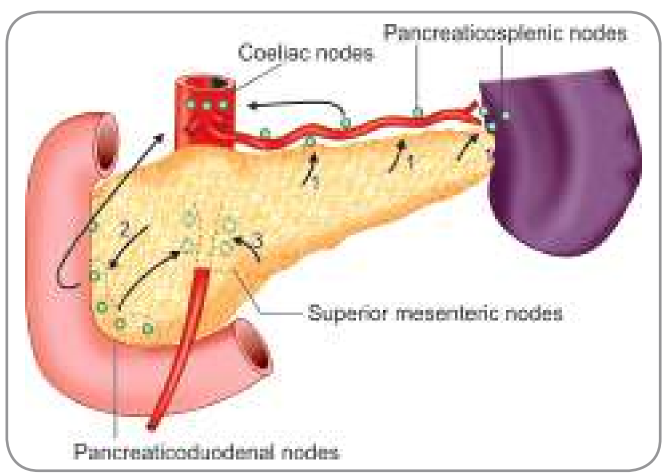


Fig. 25.13: Lymphatic drainage of pancreas
Key: 1. Lymphatics to pancreaticosplenic nodes
2. To pancreaticoduodenal nodes **3.** To superior mesenteric nodes

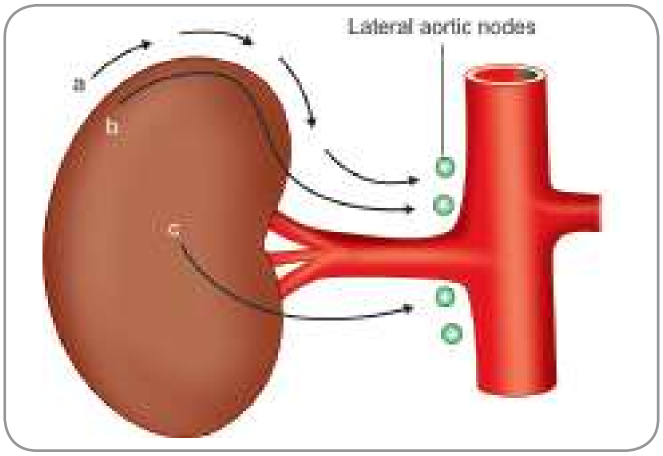


Fig. 25.14: Lymphatic drainage of kidney
Key: **a.** Nodes in perirenal fat **b.** In subcapsular area **c.** Around the renal tubules

Lymphatic Drainage of Kidney

The ***lymphatic drainage*** of the kidneys is into the lateral aortic lymph nodes. Three lymphatic plexuses (Fig. 25.14) are found: one around the renal tubules ('c'), one in the subcapsular area ('b'). and the third in the perirenal fat ('a'). The latter two plexuses freely anastomose and all of them drain into the same nodes.

Lymphatic Drainage of Ureter

The upper abdominal part of the ureter drains directly into the lateral aortic nodes. The lower abdominal part drains into the common iliac nodes. The pelvic part of the ureter drains into the external iliac and internal iliac nodes. Ultimately, all the lymph from the ureter reaches the lateral aortic nodes.

Lymphatic Drainage of Urinary Bladder

The urinary bladder drains into the external iliac lymph nodes.

Lymphatic Drainage of Urethra

The prostatic and membranous parts of the male urethra drain into the internal iliac lymph nodes. The penile part of the male urethra drains to the superficial inguinal nodes. Some lymph vessels pass through the inguinal canal and reach the external iliac nodes.

In females, the urethral lymphatics drain into both the internal and external iliac nodes.

Lymphatic Drainage of Prostate and of Seminal Vesicles

The prostate and seminal vesicles drain to both the internal and external iliac nodes.

Lymphatic Drainage of Testes and Ovaries

Lymph from the testis or ovary passes along the testicular or ovarian vessels directly to the lateral aortic lymph nodes.

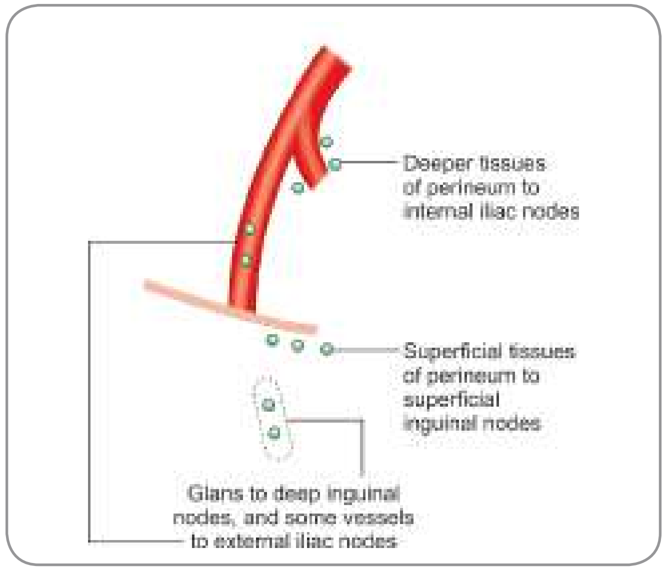


Fig. 25.15: Lymphatic drainage of perineum

Lymphatic Drainage of Perineum

Superficial structures in the perineum including the lower part of the anal canal (Fig. 25.15), the scrotum and penis in the male, and the lower part of the vagina in the female, drain into the upper medial group of superficial inguinal lymph nodes. The glans (penis or clitoris), however, drains into the deep inguinal nodes. Some lymph vessels from the glans reach the external iliac nodes. Deeper tissues of the perineum drain into the internal iliac lymph nodes.

Lymphatic Drainage of Uterus and Uterine Tube

Lymph from the uterine tube ('a' in Fig. 25.16) and from the upper part of uterus ('b' in Fig. 25.16) travels along the ovarian vessels to reach the lateral aortic nodes (Fig. 25.16). Intramural portion of the uterine tube alone drains into the superficial inguinal lymph nodes along the round ligament of uterus. Lymph from the lower part of the body of uterus ('c' in Fig. 25.16) travels to the external iliac nodes. A few vessels from the lateral angles run along the round ligament of uterus and drain into the superficial inguinal lymph nodes. Lymph from the cervix travels (Fig. 25.17) laterally to the external iliac nodes ('d' in Fig. 25.17), posterolaterally to the ***internal iliac nodes*** ('e' in Fig. 25.17) and posteriorly to the ***sacral nodes*** ('f' in Fig. 25.17). The sacral nodes lie in front of the sacrum along the median sacral artery.

Lymphatic Drainage of Abdominal Wall

Skin and Fasciae

The skin above the level of umbilicus (in front) and above the iliac crest (at the back) drains into the axillary lymph nodes. The skin of the anterior abdominal wall below the umbilicus drains into the superficial inguinal lymph nodes.

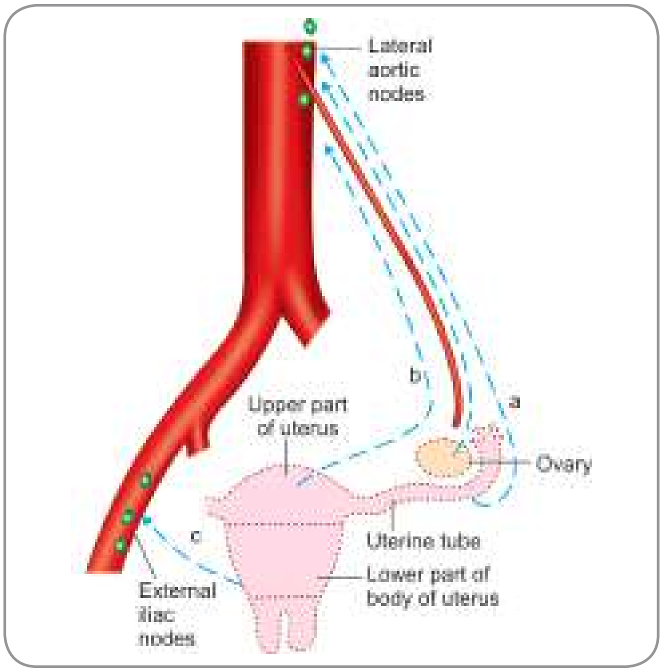


Fig. 25.16: Scheme to show the lymphatic drainage of uterus
Key: a,b,c. Lymphatic vessels from uterus

Deeper Tissues

Lymph vessels from the posterior abdominal wall travel along the lumbar vessels to the lateral aortic nodes, including the retroaortic nodes. The vessels from the upper part of the anterior and lateral part of the abdominal wall travel along the superior epigastric vessels to the parasternal nodes. The vessels from the lower part of the anterolateral abdominal wall travel along the inferior epigastric and circumflex iliac vessels. Passing through nodes placed along these vessels, they reach the external iliac nodes.

AUTONOMIC NERVES OF ABDOMEN AND PELVIS

Autonomic fibres, both sympathetic and parasympathetic, reach the thoracic and abdominal viscera through a number of plexuses. Although they are called ***plexuses***, they contain numerous neurons and are, in fact, equivalent to ganglia. Most of the sympathetic fibres passing through them are postganglionic having relayed in ganglia on the sympathetic trunk. Some are preganglionic and relay in the (ganglia of the) plexuses. Parasympathetic fibres reaching the plexuses through the vagus are entirely preganglionic. The neurons in the plexuses are mostly parasympathetic postganglionic neurons.

Dissection

Clean the posterior abdominal wall and locate the various autonomic plexuses and ganglia. Trace their branches and twigs wherever possible. Try to locate and identify a few lymph nodes. review your theory knowledge with prosected specimens.

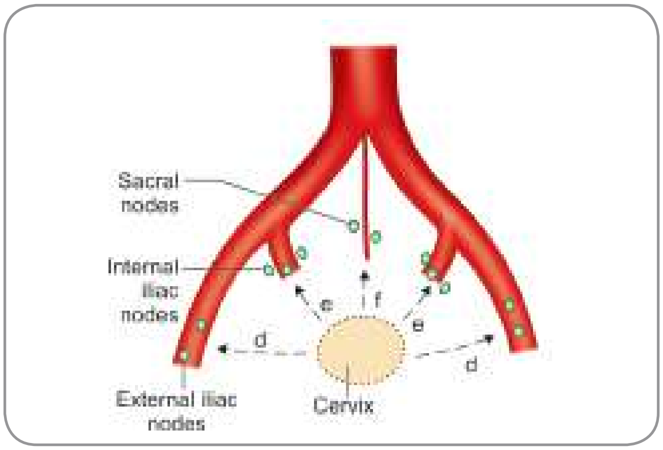


Fig. 25.17: Scheme to show the lymphatic drainage of the cervix of uterus
Key: d,e,f. Lymphatics from cervix

Autonomic Plexuses and Ganglia (Fig. 25.18)

The coeliac plexus is the uppermost part of an extensive ***aortic plexus*** surrounding the abdominal aorta. This is continued into subsidiary plexuses around the branches arising from the vessel. The ***superior mesenteric plexus*** and ***ganglia*** surround the origin of the superior mesenteric artery. There are three roots to this plexus—

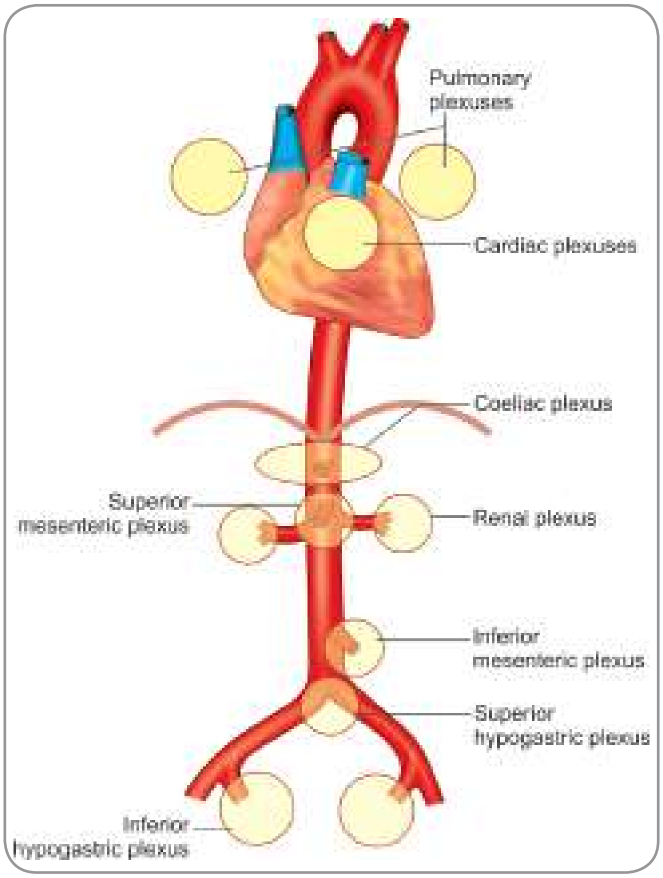


Fig. 25.18: Schematic presentation of the location of important autonomic plexuses in the thorax and abdomen

one median and two lateral. The median root is a branch from the coeliac plexus and the lateral roots are branches from the lesser and least splanchnic nerves. The ***inferior mesenteric plexus*** surrounds the inferior mesenteric artery and usually has an inferior mesenteric ganglion. It receives a medial root from the intermesenteric plexus and two lateral roots from the lumbar ganglia of the sympathetic trunks.

The part of the aortic plexus between the origins of the superior and inferior mesenteric arteries is called the ***intermesenteric plexus***. It gives rise to subsidiary plexuses—renal, testicular or ovarian and ureteric plexuses. The part overlying the bifurcation of the aorta is called the ***superior hypogastric plexus***. It gives twigs to the ureteric and testicular plexuses. When traced downwards, the lower part of the aortic plexus divides into the right and left ***inferior hypogastric plexuses*** related to the corresponding internal iliac arteries. The two inferior hypogastric plexuses (which actually lie around the urinary bladder, uterus and rectum) are connected to the superior hypogastric plexus by the right and left hypogastric nerves. They receive branches from the superior sacral sympathetic ganglia and the pelvic parasympathetic splanchnic nerves. Extensions of the inferior hypogastric plexus surround the blood vessels and form visceral plexuses, like the vesical plexus (surrounding the urinary bladder) and rectal plexus (surrounding the rectum).

The enteric parasympathetic plexuses are located in the walls of the viscera. These are the ***myenteric plexus*** (of Auerbach) between the muscle coats and the ***submucosal plexus*** (of Meissner) in the submucosa.

SYMPATHETIC NERVES IN ABDOMEN AND PELVIS

The sympathetic nerves for the abdomen and pelvis reach it through the branches of the sympathetic trunk. Some of the branches for the abdominal viscera are given off from the thoracic part of the sympathetic trunk which enter the abdomen through the crura of the diaphragm. Other branches are directly from the lumbar part of the sympathetic trunk.

Branches from the Thoracic Part of Sympathetic Trunk

The eleven thoracic ganglia of the thoracic part of sympathetic trunk give off medial and lateral branches. Lateral branches arising from each ganglion connect it to the corresponding spinal nerve by white and grey rami communicans.

The medial branches arising from the ganglia supply the viscera. Those arising from the ***upper thoracic ganglia*** are small. They supply the thoracic aorta (T2 to T6), join the posterior pulmonary plexus (T2 to T5/6) or join the deep cardiac plexus (T2 to T5). Some of them supply the trachea and the oesophagus.

The ***lower thoracic ganglia*** give origin to prominent medial branches called the ***greater, lesser and lowest splanchnic nerves*** (called the ***abdominopelvic splanchnic nerves***). Their origin is highly variable. The splanchnic nerves contain both preganglionic efferent nerve fibres and visceral afferent fibres.

- The greater splanchnic nerve is usually formed by branches from ganglia T5 to T9.
- The lesser splanchnic nerve by branches from ganglia T9 to T10 or T10–T11.
- The lowests planchnic nerve from ganglion T12.
- All these nerves pass through the diaphragm and enter the abdomen.
  - The greater splanchnic nerve ends mainly in the ***coeliac ganglion***.
  - The lesser splanchnic nerve ends in the ***aortic-renal ganglion***.
  - The lowest splanchnic nerve ends in the ***renal plexus***.

Branches from the Lumbar Part of Sympathetic Trunk

Four lumbar splanchnic nerves emerge as medial branches from the corresponding ganglia.

- The first lumbar splanchnic nerve joins the coeliac, renal and inferior mesenteric plexuses.
- The second lumbar splanchnic nerve joins the inferior part of inferior mesenteric plexus.
- The third lumbar splanchnic nerve joins the superior hypogastric plexus and
- The fourth lumbar splanchnic nerve joins the inferior part of superior hypogastric plexus.

Apart from the splanchnic branches, vascular branches also reach the aortic plexus. From here they extend into plexuses on the common iliac, internal iliac, external iliac, and the proximal parts of the femoral arteries.

Branches from the Sacral Part of Sympathetic Trunk

This part of the trunk bears four or five ***sacral ganglia***. In front of the coccyx, the right and left sympathetic trunks both end in a median ganglion, the ***ganglion impar***. The branches arising from the pelvic part of the sympathetic trunk join the inferior hypogastric plexus.

Preganglionic centres of abdominopelvic organs: The following are the spinal segments which give rise to the preganglionic sympathetic fibres for the abdominopelvic organs.

Oesophagus and stomach	T6–T9
Small intestine	T9–T10
Large intestine	T11–L2
Suprarenal gland	T8–L1
Kidney	T10–L1
Urinary bladder	T11–L2
Testes/ovary	T10–T11
Uterus	T12–L1

Innervation to lower limbs from lumbar and sacral ganglia: The lumbar and sacral sympathetic ganglia are also concerned with the sympathetic innervation of the lower limbs.

The preganglionic fibres concerned arise from neurons in the lateral grey column of spinal segments T10 to L2 (or L3).

They pass through the corresponding spinal nerves, and white rami arising from them, into the sympathetic trunk. Postganglionic fibres travel as follows:

i. Some fibres arising in the lumbar ganglia travel through the plexuses on the aorta, the common iliac and external iliac arteries to innervate the proximal part of the femoral artery.
ii. Some fibres arising in the lumbar ganglia pass through the grey rami into the lumbar nerves, and through them into the femoral nerve. They pass through the branches of the femoral nerve to supply the distal part of the femoral artery.
iii. Fibres arising in sacral ganglia pass through the grey rami to the sacral nerves, and through them into the tibial nerve. Travelling through this nerve, they reach the popliteal artery and its branches.

PARASYMPATHETIC NERVES IN ABDOMEN AND PELVIS

The parasympathetic nervous system consists of a ***cranial part*** and a ***sacral part***.

Preganglionic neurons of the ***cranial part*** are located in the brainstem (general visceral efferent nuclei of the cranial nerves). Details of these will be considered in the section on Head and Neck.

a. The preganglionic fibres arising from them pass through the third, seventh, ninth and tenth cranial nerves. They collectively constitute the ***cranial parasympathetic outflow***.
b. The only fibres of this outflow relevant to the abdomen are those that travel through the vagus nerve (tenth cranial nerve).

Postganglionic neurons of the ***cranial part*** of the parasympathetic nervous system are located in a number of ganglia present in association with the branches of the cranial nerves concerned. Usually, the ganglia of the parasympathetic system lie very close to or within the substance of the organ that it supplies. Postganglionic neurons related to the vagus nerve are scattered in the autonomic plexuses.

Preganglionic neurons of the ***sacral part*** of the parasympathetic nervous system are located in the sacral segments of the spinal cord (intermediolateral grey column in spinal segments S2, S3 and S4). Their axons constitute the ***sacral parasympathetic outflow*** and are concerned with the innervation of the viscera in the abdomen and pelvis. Postganglionic neurons are very short and are located within the plexuses.

Branches of Vagus Nerve Related to Abdomen

Of the four cranial nerves linked to the parasympathetic nervous system, only the branches of the vagus nerve supply the viscera of abdomen and pelvis. Of the branches of vagus given out in the thoracic cavity, the branches which supply the oesophagus form an anterior and a posterior oesophageal plexus within the thoracic cavity. The fibres emerging from the lower end of the anterior oesophageal plexus continue as the ***anterior vagal trunk*** which is made up mainly of fibres of the left vagus nerve. Similarly, fibres arising from the posterior oesophageal plexus (derived mainly from the right vagus) continue as the ***posterior vagal trunk***. These two trunks enter the abdomen through the oesophageal opening in the diaphragm. They are responsible for the parasympathetic supply to the greater part of the gastrointestinal tract and to some other organs.

Preganglionic neurons which constitute the ***sacral parasympathetic outflow*** are located in the intermediolateral grey column in spinal segments S2, S3 and S4 (Figs 25.19A and B). They emerge from the spinal cord through the ventral nerve roots of the corresponding spinal nerves and soon leave them through their ***pelvic splanchnic branches***.

The preganglionic fibres end in relation to postganglionic neurons which are located either in the walls of the viscera supplied or in plexuses related to them (Figs 25.20A and B).

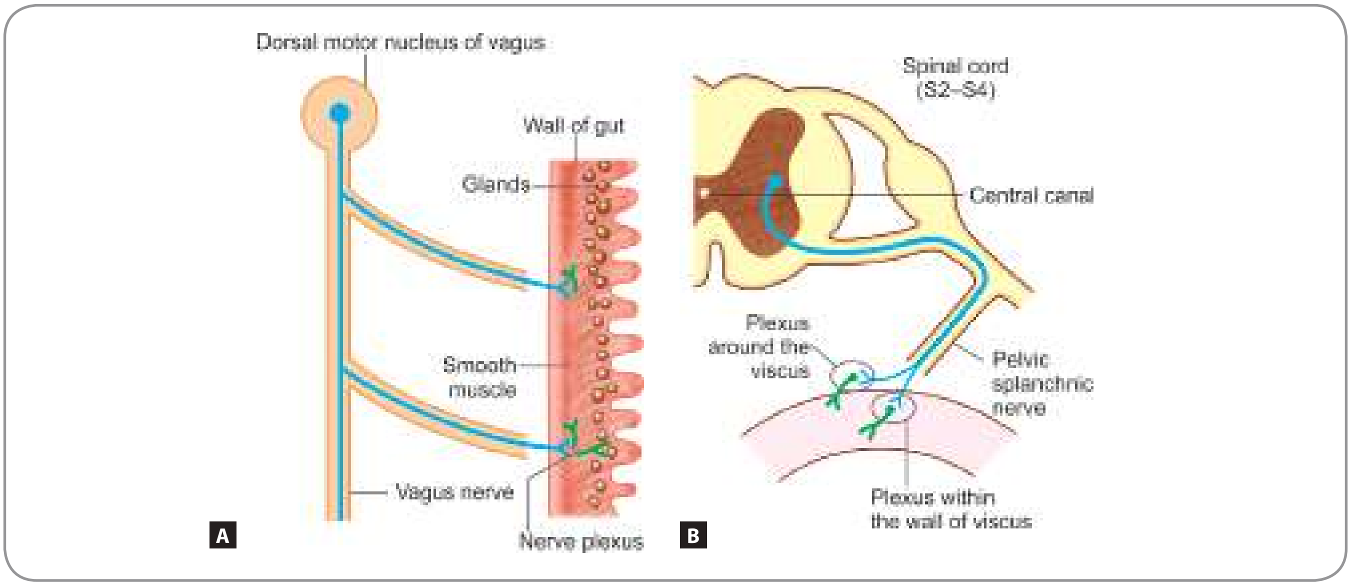
The organs supplied directly by the pelvic splanchnic nerves are the:

- Urinary bladder
- Rectum
- Testes or ovaries
- Uterus
- Uterine tubes
- Penis or clitoris.

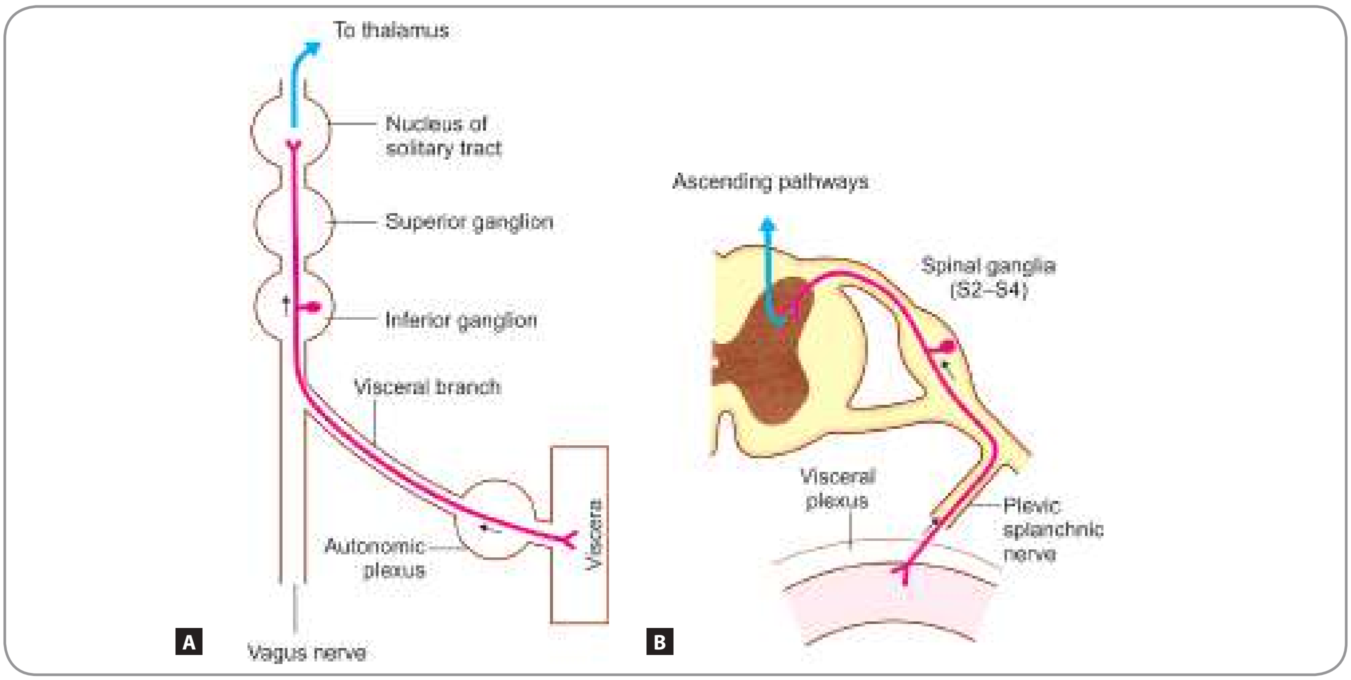
Some fibres of these nerves pass through the hypogastric plexuses to supply the pelvic colon, the descending colon and the left one-third of the transverse colon (Note that all these parts of the gut so supplied are hindgut derivatives).

Afferent Autonomic Pathways

Both the sympathetic and parasympathetic nerves carry numerous afferent fibres which are classified as ***general visceral afferent fibres***. The cell bodies of the afferent nerves are located in the concerned dorsal nerve root



Figs 25.19A and B: Efferent autonomic neurons **A.** Neurons related to the vagus **B.** Neurons passing through the pelvic splanchnic nerves



Figs 25.20A and B: Arrangement of afferent autonomic neurons **A.** Nerve fibres passing through the vagus nerve **B.** Nerve fibres passing through the sympathetic nerves

ganglia of spinal nerves, or in the sensory ganglia of cranial nerves. They carry impulses arising in the viscera and in the blood vessels to the central nervous system (Fig. 25.20A and B).

Afferents Related to Cranial Parasympathetic Nerves

In general, these are the general visceral afferent fibres of cranial nerves, and the fibres that carry afferent impulses from the abdomen belong to the vagus nerve. The cell bodies of the neurons concerned are located in the various plexuses already discussed before in this chapter. The central processes of the neurons pass through the vagus nerve to reach the brain (medulla oblongata) where they terminate in the nucleus of the solitary tract.

The peripheral processes innervate visceral structures (Figs 25.19A and B). Sensory fibres carried by the vagus innervate all organs to which its efferent fibres are distributed.

Afferents Related to Sacral Parasympathetic Nerves

These afferent fibres are peripheral processes of pseudounipolar neurons located in the dorsal root ganglia of the second, third and fourth sacral nerves (Figs 25.19A and B). These fibres run through the pelvic splanchnic nerves to innervate pelvic viscera. The central processes of these neurons enter the spinal cord. The spinal pathways carrying afferent impulses from the viscera are not fully established.

Afferents Related to Sympathetic Nerves

Afferent fibres accompany almost all efferent sympathetic fibres. These afferent fibres are the peripheral process of pseudounipolar neurons located in the dorsal root ganglia of spinal nerves T1 to L2 or L3.

Autonomic afferents are necessary for various visceral reflexes. Most of these impulses are not consciously perceived. Some normal visceral sensations that reach consciousness include those of hunger, nausea, rectal distension and sexual sensations. Under pathological conditions, visceral pain is perceived. This is produced by distension, by spasm of smooth muscle or by anoxia.

Though the afferents of sympathetic and parasympathetic are discussed separately, the sensory impulses from the same organ may travel along both the sympathetic and parasympathetic nerves.

Multiple Choice Questions

1. The retro-aortic lymph nodes are outlying members of the:
   a. Lateral aortic group
   b. Pre-aortic group
   c. Coeliac group
   d. Inferior mesenteric group

2. Pyloric lymphatics drain into which group of nodes before reaching the hepatic nodes?
   a. Left gastric nodes
   b. Pyloric nodes
   c. Right gastric nodes
   d. Coeliac nodes

3. Epicolic nodes lie:
   a. Along the inner border of colon
   b. In the walls of colon
   c. At the ileocaecal junction
   d. Within the transverse mesocolon

4. Which of these is not part of the abdominopelvic group though found in abdominal area?
   a. Greater splanchnic nerve
   b. Lesser splanchnic nerve
   c. Lowest splanchnic nerve
   d. Lumbar splanchnic nerve

5. Cell bodies of general visceral afferent fibres have their cell bodies in
   a. Dorsal root ganglia
   b. Aortic plexus ganglia
   c. Ganglia in visceral walls
   d. Ganglia along arteries

ANSWERS

1. a **2.** b **3.** b **4.** d **5.** a

Chapter 26

Cross-Sectional, Radiological and Surface Anatomy of Abdomen and Pelvis

Frequently Asked Questions

- Write a note on Morris parallelogram.
- Write short notes on Intravenous pyelography.
- Write ultra short notes on: (a) Surface marking of duodenum (b) Surface marking of Liver (c) Surface marking of spleen (d) Surface marking of Inguinal canal (e) Surface marking of Pancreas

CROSS-SECTIONAL ANATOMY OF ABDOMEN AND PELVIS

The abdominal and pelvic cavities contain several important viscera. Many of these viscera have periodic and irregular variations of size and shape; many of them also move atleast by a few millimeters. It is, therefore, very essential to have a clear image of their relationships to each other and to their environs. Study of the cross-sectional anatomy of abdomen and pelvis gains more significance than such studies of other anatomical regions.

The cross-sectional anatomy of abdomen and pelvis can be studied at four different levels for understanding the general disposition of viscera. However, it should be remembered that in the living, microsections at nanometric levels may show differences, especially in diseased conditions; computed tomography (CT) and magnetic resonance imaging (MRI) sectional studies attain great significance in deciding management modalities.

For a comprehensive understanding of the disposition of the abdominal and pelvic viscera, a study of the cross-section of the region at four different levels are required.

TRANSVERSE SECTION AT THE LEVEL OF T10 VERTEBRA

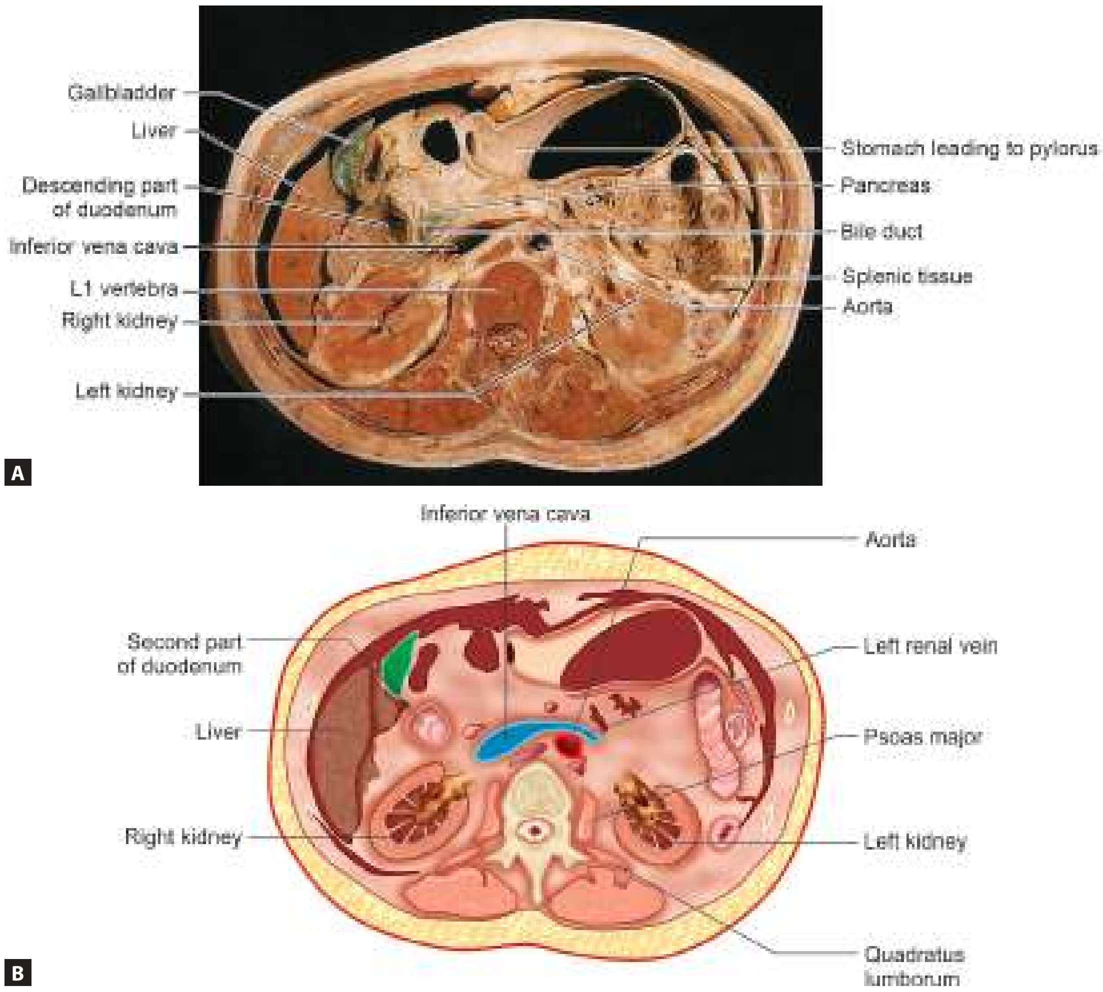
This section passes through the xiphoid process. This level corresponds to the oesophagogastric junction. The section is not completely abdominal and cuts through the domes of the diaphragm and so, structures related to the domes are seen. The oesophageal orifice, surrounded by the right and the left crura, lies a little to the left and anterior to the vertebra. Between this orifice and the vertebra is seen the aorta. The inferior vena cava can be made out on the right anterolateral aspect of the vertebra. Since the section passes through both the thoracic and abdominal cavities, the lower parts of the lungs in the costodiaphragmatic recesses can also be seen on either side. The structure seen to fill the right side is the liver; the hollow of the stomach can be made out on the left and clinging to the left visceral aspect of the liver. The superior part of spleen is also seen. Important structures seen in the midline are the part of pylorus, tail of pancreas, division of the coeliac trunk and the abdominal aorta.

TRANSVERSE SECTION AT THE LEVEL OF T12 VERTEBRA (FIG. 26.1)

This section passes inferior to the xiphoid process. The pyloric antrum, pyloric canal and coils of intestine occupy the left side and the liver occupies the right side. The gall bladder first appears in this section (as a serial study is done from above downwards). Important structures seen in the midline are the part of the pylorus, tail of pancreas, division of the coeliac trunk the abdominal aorta. The right and left crura are seen in this section also. The superior poles of the kidneys with the suprarenal glands are seen. The portal triad with common bile duct, proper hepatic artery and portal vein are prominent features in this section. The splenic hilum with the splenic vessels may also be seen.

TRANSVERSE SECTION AT THE LEVEL OF L1–L2 VERTEBRAE (FIG. 26.2)

This section cuts just below the transpyloric plane.The pylorus may be found in this section, but is not a constant finding. The liver occupies a much smaller region and a



Figs 26.1A and B: Transverse section at the level of lower part of L1 vertebra – seen from below—the section has passed just below the superior mesenteric artery and therefore the left renal vein is seen

major portion of the cavity is occupied by coils of intestine. The Hila of both kidneys with renal vessels are a prominent feature. Other important structures in the midline are the uncinate process of pancreas, origin of superior mesenteric artery and superior mesenteric vein.

TRANSVERSE SECTION AT THE LEVEL OF L3-L4 VERTEBRAE (FIG. 26.3)

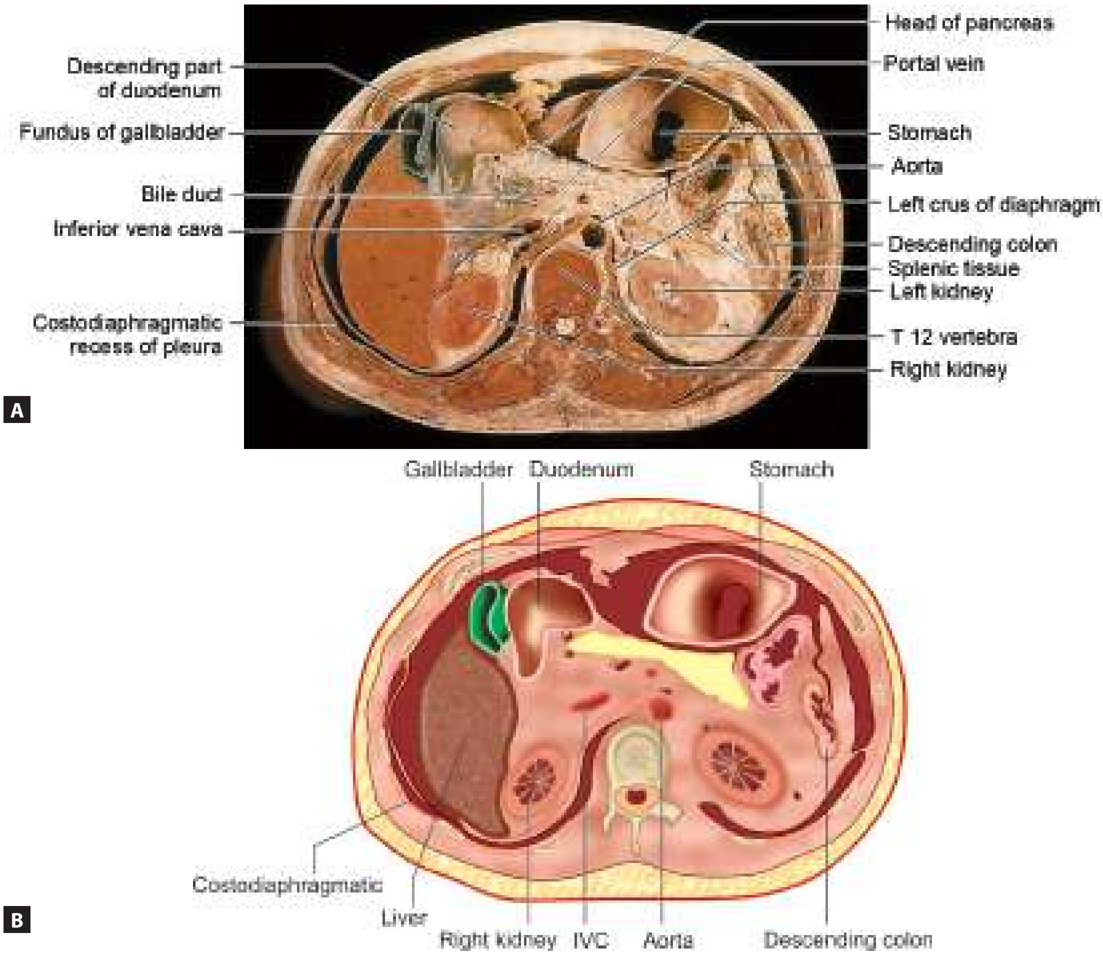
The most prominent feature in this section is the presence of the coils of intestines suspended by mesentery. Various folds of the mesentery can be distinguished. The three abdominal wall muscles—(1) transversus abdominis, (2) internal oblique and (3) external oblique are well seen. Various primary and secondary branches of the abdominal aorta are seen in the mesentery. The inferior vena cava is seen to right of the aorta. The peritoneum is clearly made out separating the abdominal cavity from the subperitoneal fatty layer. The three layers of thoracolumbar fascia and the pre and para vertebral muscles may also be noted (Fig. 26.3A and B).

RADIOLOGICAL ANATOMY OF ABDOMEN

Most of the viscera of the abdomen, especially those of the digestive tract are hollow organs. Air is either completely or partially present within them. Other viscera, though not hollow, are made up of soft tissue. Examples of the latter are the liver and the pancreas. Radiographs do not give complete information of the abdominal viscera as they would so, in the case of a bone. However, density and opacity variations do provide with reliable information. In addition to the regular plain X-ray pictures, higher and advanced radiographic methods are used to get better and appropriate information.

PLAIN X-RAY ABDOMEN–ANTEROPOSTERIOR VIEW (FIG. 26.4)

This study is also called the ***KUB study*** (Kidney–Ureter – Bladder study) since the important structures studied are the kidney, ureter and urinary bladder. The kidneys are seen as clear shadows on either side of the vertebral column.



Figs 26.2A and B: Transverse section at the level of T12 vertebra seen from below—the section has passed just above the coeliac trunk

Bony points seen are the lumbar vertebrae, lower ribs, sacroiliac joints, coccyx, iliac crests and symphysis pubis. The spines of the vertebrae present a linear arrangement in the midline. Alterations in bony arrangements and joint position should be checked for. Fractures of lower ribs, lordotic, kyphotic and scoliotic changes of the lumbar vertebral column and alterations in the area of symphysis pubis, if present, can be made out fairly well.

The domes of the diaphragm may be seen if the radiograph covers the abdominothoracic junction. The relative position of both the domes can be compared and analysed. Fundus of the stomach is seen as a translucent area below the left dome of the diaphragm. Liver is seen below the right dome. Enlargement of liver, if any, should be looked for. An enlarged gallbladder may appear beneath the inferior margin of the liver. Bowel gas is seen as irregular translucent masses, sometimes overlapping the renal shadow.

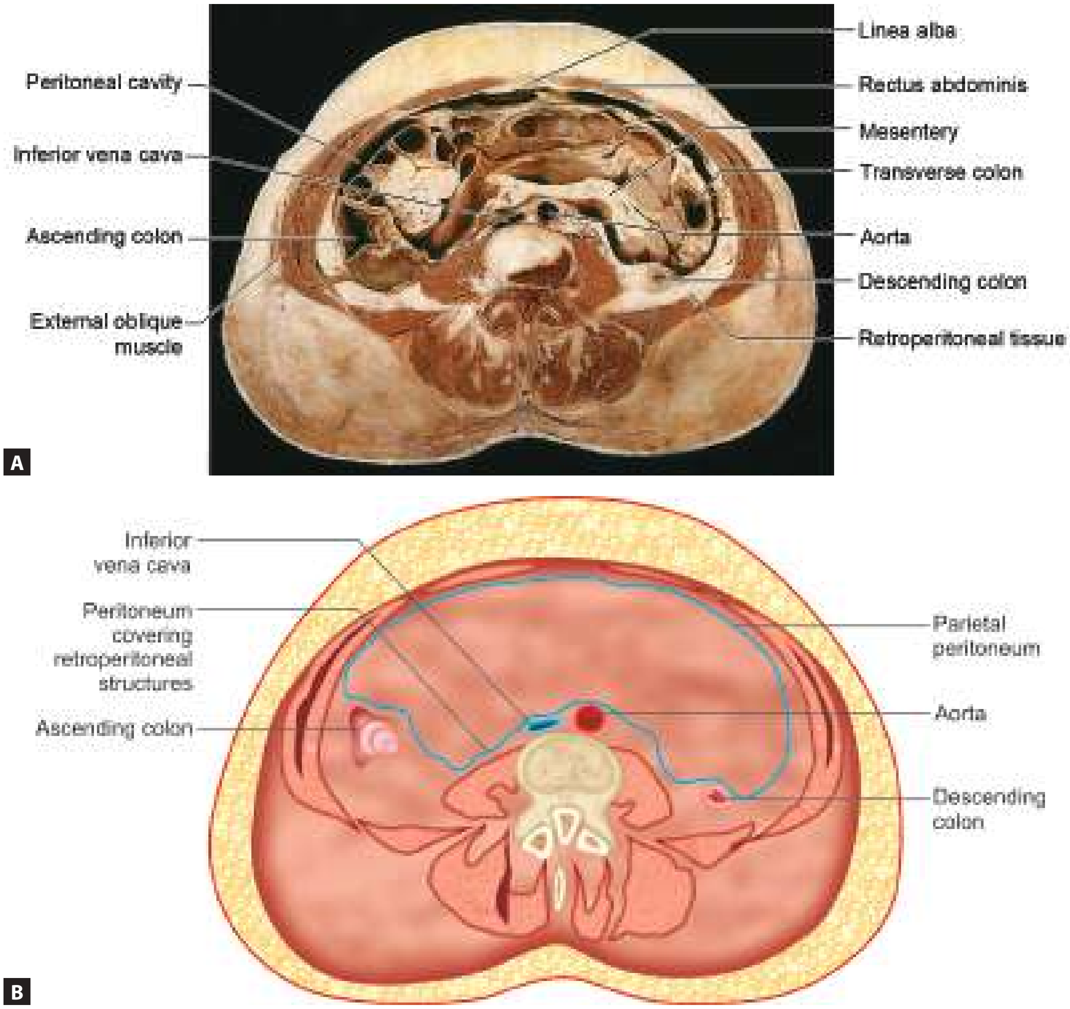
KUB study is useful in cases of renal and gallbladder calculi, paralytic ileus and rupture of hollow viscus.

CONTRAST RADIOGRAPHY

X-ray pictures are taken after giving contrast medium (Figs 26.5A and B) to the individual either orally or intravenously. Various hollow organs or vessels are made opaque by means of the contrast material (which by itself is a radiopaque substance). Alterations in the shape, size and patency of the organ/vessel can be made out.

- ***Visualisation of digestive tract-barium studies***: Barium sulphate solution acts as a good radiopaque substance. Various kinds of barium studies are undertaken. The oesophagus is visualised by making the patient swallow barium sulphate solution and the radiograph is taken during deglutition. This is a ***barium swallow*** picture.

The patient is given barium sulphate solution orally; X-ray pictures at timed intervals so that the stomach is visualised with variable amounts of barium. Gastric filling and emptying are thus studied. As the stomach empties, barium will go into the duodenum. Erosions of gastric and duodenal mucosa will cause abnormal contour of



Figs 26.3A and B: Transverse section at the level of lower part of L3 vertebra–seen from below

the concerned surfaces. Any lump or mass occupying the lumen or projecting from any of the walls can be made out as these would also cause changes in the contour. This is a ***barium meal*** picture (Fig 26.6).

With more pictures taken at definitive intervals, even the small intestine can be visualised in a barium meal study.

To study the large intestines, the patient is given an enema of barium and the colon is visualised. This is a ***barium enema*** study (Fig. 26.7).

- Normal and altered Radiological appearances of various viscera of the digestive tract in barium studies (Fig. 26.7):
  - ***Stomach:*** The outline of the stomach can be made out, the shape and size of which varies among individuals. The fundus is seen as a translucent area near the cardiac end. The pylorus is seen as a small column of barium with parallel walls extending from the antrum.
  - ***Duodenum:*** The first part is seen clearly as a solid mass extending from the pylorus; the contour presents a cap like appearance and hence is called the ***duodenal cap***. Irregularities in the mucous membrane (produced by ulcers or erosions) cause distortion of the duodenal cap. In such cases, loculation of barium in the duodenal cap is noted. Other parts are seen as flocculated masses of barium.
  - ***Small intestine:*** The jejunum and ileum present a feather like appearance.
  - ***Large intestine:*** The colon shows sacculations. The descending colon appears narrower than the ascending colon. The pelvic colon is seen as a wide loop. The hepatic and splenic flexures show superimposed loops.
- Visualisation of urinary tract
  - ***Pyelography***: The outflow urinary tract can be visualised by suitable contrast material flowing through the renal calyces and ureters. This can be achieved by injecting intravenous contrast medium. The contrast material circulates in blood

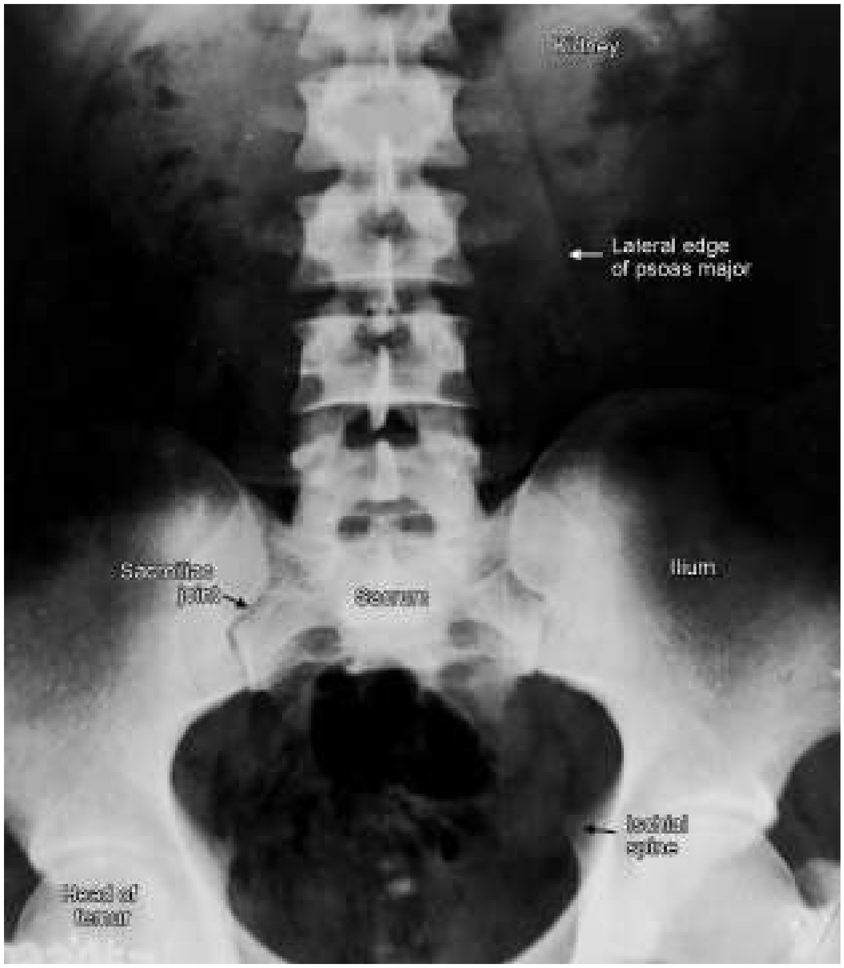


Fig. 26.4: Plain radiograph of the abdomen. Note the shadows of lumbar vertebrae. In each vertebra identify the vertebral bodies. The gaps between them represent areas occupied by intervertebral discs. Also note the spinous and transverse processes. The sacrum is seen articulating with the hip bones at the sacroiliac joints. The upper parts of the heads of the right and left femur are seen. Soft tissues that can be identified are the lateral edges of the psoas major muscles, and the kidneys. The irregular black areas over the kidney region, and in the pelvis are caused by gas present in the intestines

and then passes through the renal filter system. As it passes through the urinary tract, the component structures are visualised. Serial X-ray pictures are taken. This study is called ***intravenous pyelography*** (***or descending pyelography***). Pictures taken are ***intravenous pyelogram*** or ***descending pyelogram/ urogram***.

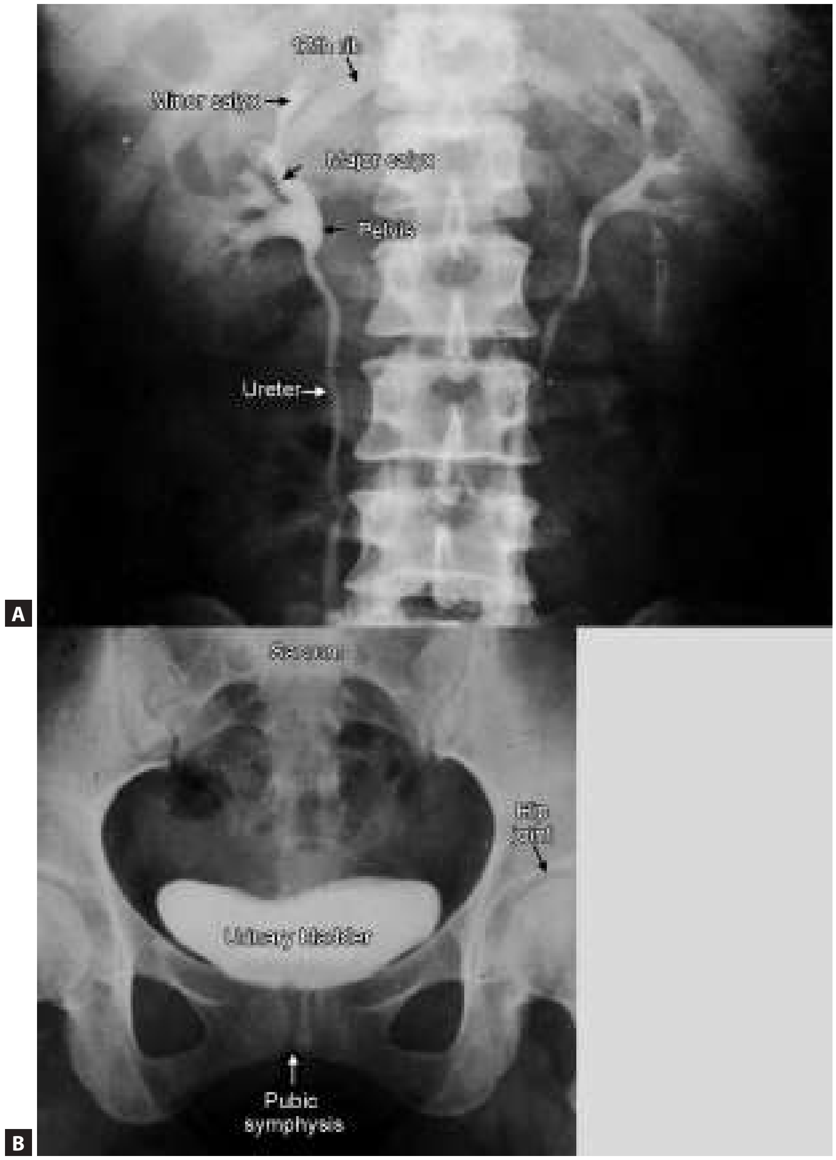
If the contrast dye is introduced into the urethra and bladder and made to show the component structures of the urinary tract, the procedure is called ***retrograde pyelography*** (or ***ascending pyelography***). The picture taken is an ***ascending pyelogram/urogram***.

Structures visualised in pyelography are the major and minor calyces, pelvis of the ureter, ureter and urinary bladder. In a retrograde pyelogram, the cystoscope inside the bladder and catheter in the urethra/ureter (the instruments or appliances through which the dye was delivered to the required spot) can also be seen.

In interpreting such urograms, it is important to know the skeletal relationships of the ureters.

- The abdominal part runs downwards in line with the tips of the transverse processes of lumbar vertebrae;
- After entering the pelvis, the ureter runs across the sacroiliac joint, and the anterior border of the greater sciatic notch to reach the ischial spine;
- The ureter turns medially at this spine. Its point of termination corresponds to the pubic tubercle.

In obstruction to the urinary outflow tract, the portions of the tract proximal to the obstruction may be dilated. Thus, dilatation of the ureter (hydroureter) or of the renal pelvis and calyces (hydronephrosis) may be seen. In descending pyelography, the portion of the tract distal to the obstruction may not be visualised either completely or partially as the excretion of dye would have been hampered by the obstruction.



Figs 26.5A and B: A. Radiographs taken after intravenous injection of a contrast medium that is excreted by the kidneys (intravenous pyelography). In radiograph 'A' taken soon after injection, the calyces, and part of the ureters are seen **B.** In radiograph 'B' taken some time later, the urinary bladder is outlined

- ○ ***Cystography***: This is a procedure followed for the visualization of the lower urinary tract. The dye is injected into the urinary bladder through a cystoscope. The urinary bladder can be well seen in this method.
- ❑ ***Visualisation of biliary tract—cholecystography (Fig. 26.8A):*** The contrast is introduced orally or intravenously (oral or intravenous cholecystography respectively). It is excreted by the liver and concentrated by the gall bladder, rendering the latter opaque. The gallbladder appears as pear shaped mass between the twelfth rib and the upper lumbar vertebrae. The position and shape can vary among individuals. Non visualisation of the gallbladder can be because of liver impairment, malfunctioning of gallbladder or obstructive liver disease.
- ❑ ***Visualisation of the female genital tract—hysterosalpingography (Fig. 26.8B)***: Contrast introduction techniques may be adopted to visualise the female genital tract. The fallopian tubes and their patency levels are usually studied by these techniques.

IMPORTANT LINES AND AREAS

- ❑ ***Linea alba:*** A linear midline groove visible in the lean and muscular individuals extending from xiphoid process to pubic symphysis. It lies between the two recti and is formed by the decussating and interlacing aponeurotic fibres of external oblique, internal oblique and transverses abdominis.

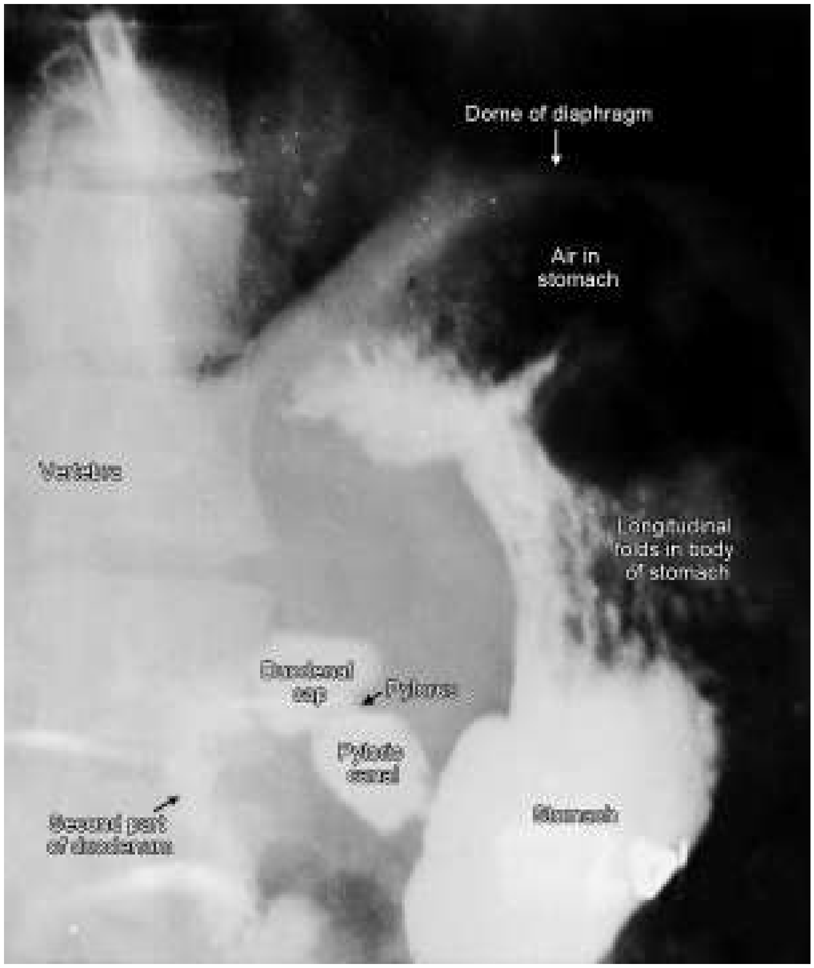


Fig. 26.6: Radiograph of upper abdomen (oblique view) after a barium meal. The lower part of the stomach, and part of the duodenum, are outlined. Note the characteristic shape of the duodenal cap

- ***Linea semilunaris:*** A curved groove visible on either side of the linea alba extending from the tip of the ninth costal cartilage to the pubic tubercle. It corresponds to the lateral margin of the rectus abdominis (5 to 8 cm from the midline).
- ***Costal margins:*** The line formed by the union of the medial borders of the 7th to 10th costal cartilages on either side of the epigastric fossa; this margin serves as a line of demarcation between the thoracic and the abdominal cavities.
- ***Upper horizontal plane:*** Otherwise called the transpyloric plane (as it corresponds to the pyloric end of the stomach) or Addison's superior clinical plane. It is indicated by a line encircling the body at the level midway between the umbilicus and the xiphisternal joint or at a level of hand's breadth below the xiphisternal joint. It passes through the body of the first lumbar vertebra at the back and tip of the ninth costal cartilage in the front.
- ***Lower horizontal plane:*** Otherwise called the transtubercular or intertubercular plane or Addison's inferior clinical plane. It is indicated by a line encircling the body at the level of the tubercles on the iliac crests. At the back, it passes through the upper border of the fifth lumbar vertebra.
- ***Subcostal plane:*** It is the third horizontal plane , represented by a line encircling the body at the level of the most dependent parts of the tenth costal cartilages. It passes through the upper border of the third lumbar vertebra.
- ***Supracristal plane:*** A horizontal plane passing through a line connecting the highest points of the iliac crests on the posterior surface of the trunk. It passes through the spinous process of the fourth lumbar vertebra.
- ***Right and left lateral planes:*** The two vertical planes, on either side, passing through the midpoint between the pubic symphysis and the anterior superior iliac spine (midinguinal point). These lines are also called the

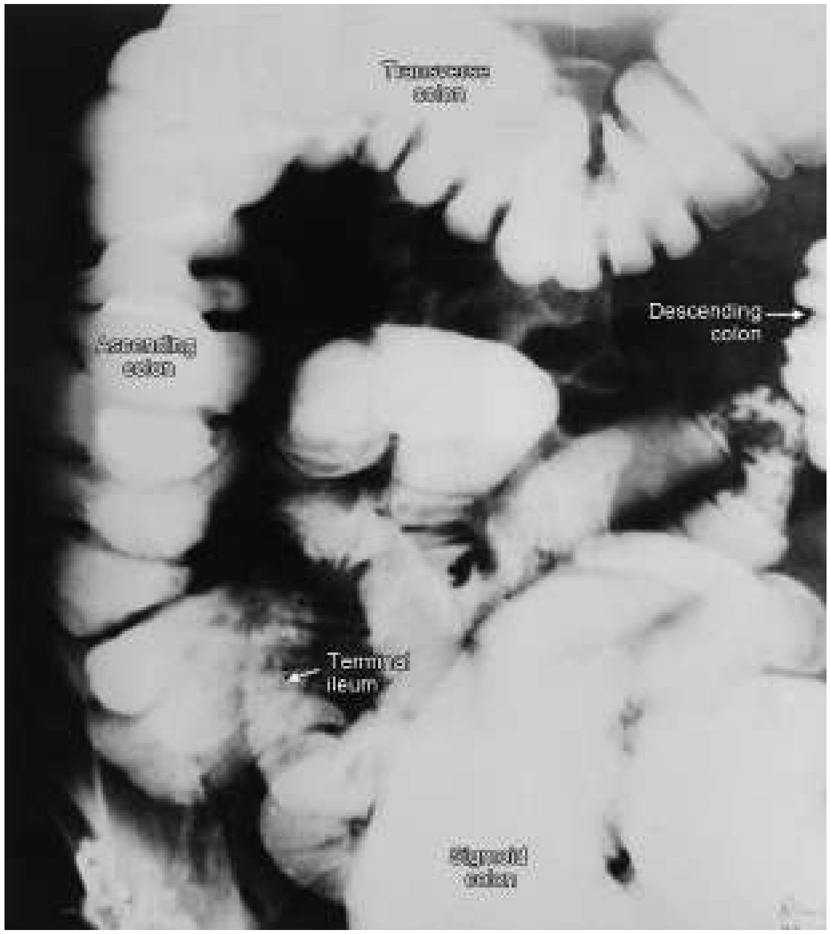


Fig. 26.7: Radiograph of abdomen after a barium enema. The colon is outlined

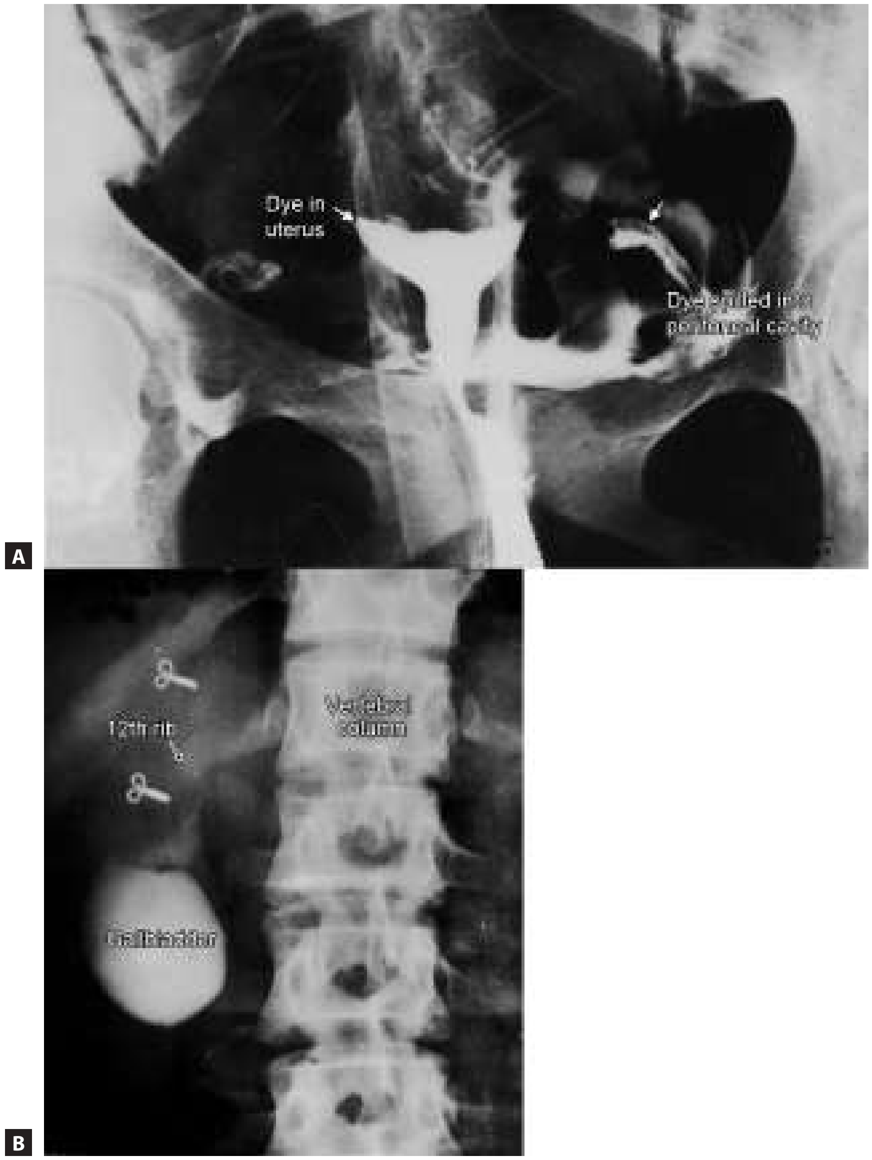
midclavicular lines as they pass through the midpoints of the clavicula when extended to the thorax.

- ***Inguinal grooves:*** The skin creases parallel, but inferior to the inguinal ligaments.
- ***Regions of abdomen:*** The abdomen is conveniently divided into nine regions by means of the upper and lower horizontal planes and the two vertical planes. The upper and lower horizontal planes divide the abdomen into three zones. Each zone is further subdivided into three regions by the right and left lateral planes. The median region of the upper zone is the epigastric region; the right and left are the right and left hypochondriac regions. The median region of the middle zone is the umbilical region; the right and left are the right and left lumbar regions. The median region of the lower zone is the hypogastric or pubic region; the right and left are the right and left iliac or inguinal regions.
- ***Epigastric fossa:*** Otherwise called the pit of the stomach, this is a slight depression in the epigastric region immediately inferior to the xiphoid process.
- ***Umbilicomammary triangle:*** A triangle with its apex at the umbilicus and base formed by the line joining the two nipples.
- ***Elaut's triangle:*** A triangle formed by the two common iliac arteries with the sacral promontory.
- ***Labbe's triangle:*** A triangle bounded inferiorly by a transverse line drawn along the lower border of left ninth costal cartilage, laterally by the line of the false ribs and to the right (medially) by liver; the stomach is in contact with the abdominal wall here.
- ***Lumbar triangle of petit:*** A triangle on the posterior abdominal wall, bounded by the inferior border of latissimus dorsi, posterior border of external oblique and iliac crest; an area for herniation.
- ***Marcille's triangle:*** A triangular area bounded by medial border of psoas major, lateral border of vertebral column and superior aspect of iliolumbar ligament; The obturator nerve runs in this area.

SUPERNUMERARY BONES

The abdominopelvic region does not have many bones. However, the incidence of one important bony variation of the region should be remembered.

Presence of a lumbar rib; the first lumbar vertebra may rarely present with a rudimentary rib or a fibrous cord.



Figs 26.8A and B: A. Hysterosalpingography. Contrast medium has been injected into the uterus, and has passed through the uterine tubes to spill into the peritoneal cavity. This indicates that the uterine tubes are patent **B.** Cholecystography. A suitable contrast medium, administered orally, has been absorbed by the gut, and excreted by the liver in bile. As the bile is concentrated in the gall bladder the organ is outlined

Usually symptomless, it may sometimes be the cause for pressure symptoms.

SURFACE MARKING OF IMPORTANT BONY POINTS AND STRUCTURES OF ABDOMEN

BONY POINTS AND LEVELS

- ***Iliac crest:*** It forms the lower limit of the waist. It can be felt by placing a hand on the hip. The hand rests on the ipsilateral iliac crest. Its anterior and posterior extremities are called the anterior and posterior superior iliac spines respectively.
  - ***Anterior superior iliac spine:*** It is felt at the lateral end of the fold of the groin. It is also the rounded point where the iliac crest ends anteriorly. It can be clearly made out in thin individuals.
  - ***Posterior superior iliac spine:*** It cannot be felt, but can be marked on the surface as it is indicated by dimples on either side of the natal cleft.
- ***S2 spine:*** It lies in the middle of the line joining the two posterior superior iliac spines.
- ***Tubercle of the iliac crest:*** It lies 5 cm behind the anterior superior iliac spine. It marks the widest point of the iliac crest and can be palpated by running a finger posteriorly from the anterior superior iliac spine.

- ***Bodies and superior rami of pubic bones:*** These can be palpated about a hand's breadth below the umbilicus.
- ***Pubic crest:*** It is the rounded upper border of the body of pubis, felt lateral to the pubic symphysis.
- ***Pubic tubercle:*** It is the rounded projection at the lateral end of the pubic crest. It can be felt approximately 2 cm from the pubic symphysis. In males, it is usually obscured by the spermatic cord.
- ***Pubic symphysis:*** It is felt at the lower end of the median plane.
- Markings of these planes and structures can be coincided with vertebral levels.
  - ***Transpyloric plane:*** L1
  - ***Subcostal plane:*** L3
  - ***Umbilicus:*** disc between L 3 and L4
  - ***Highest point of iliac crest:*** Between L3 and L4.
  - ***Supracristal plane:*** L4
  - ***Transtubercular plane:*** L5
  - ***Posterior superior iliac spine:*** S2

LANDMARK SOFT TISSUE POINTS

- ***Umbilicus:*** It is the puckered depression in the median plane. Its position varies with age and tone of abdominal muscles. In young individuals it lies at the level of the disc between the third and fourth lumbar vertebrae. In old age, due to the lack of tone of abdominal muscles, it sinks to a lower level. It lies low in children because of the underdevelopment of the pelvic region.
- ***Superficial inguinal ring:*** It is marked as a triangular opening 1 cm lateral and 1 cm above the pubic tubercle.
- ***Deep inguinal ring:*** The deep ring is marked as an oval opening, 1.25 cm above the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis.
- ***Inguinal canal:*** The inguinal canal is represented by two parallel lines joining the upper and lower edges of the deep and superficial inguinal rings. The lines are oblique, about 4 cm long, run downwards and medially above the medial half of the inguinal ligament.
- ***Mc burney's point:*** Point A is marked at the anterior superior iliac spine. Point B is marked at the umbilicus. The line joining the two points is called the ***spinoumbilical line***. It is divided into three equal parts. The junction of the medial two thirds and the lateral one third represents the Mc Burney's point on the surface. It is the point of maximum pain during inflammation of the appendix, but it does not correspond to the level of the ileocaecal orifice.

VESSELS OF ABDOMEN

- ***Abdominal aorta:*** Point A is marked 2.5 cm above the transpyloric plane in the midline. Point B is marked 1.2 cm below and to the left of the umbilicus. Two parallel lines 2 cm wide, connecting the above two points indicate abdominal aorta on the surface.
- ***Coeliac trunk:*** It is marked on the surface as a small circle in the median plane 2.5 cm above the transpyloric plane.
- ***Left gastric artery:*** Point A is marked 2.5 cm above the transpyloric plane on the midline (indicating the coeliac trunk). Point B is marked on the left seventh costal cartilage 2.5 cm to the left of the midline (indicating the cardiac orifice). A line connecting the two points represents the left gastric artery on the surface. It runs upwards and to the left.
- ***Splenic artery:*** Point A is marked 2.5 cm above the transpyloric plane on the midline. Point B is marked 10 cm to the left of Point A, but about 1 cm above. A tortuous line connecting the two points indicates splenic artery on the surface.
- ***Hepatic artery:*** Point A is marked 2.5 cm above the transpyloric plane on the midline. Point B is marked 2.5 cm below and to the right of point A. Point C is marked 2–3 cm vertically above point B. Points A and B are connected by line which runs upwards and to the right. Points B and C are joined by a line which runs upwards. The whole stretch marks the hepatic artery on the surface.
- ***Superior mesenteric artery:*** Point A is marked at the junction of the median and transpyloric planes. Point B is marked at the junction of the right lateral and the transtubercular planes. The two points are connected by a line that is curved with a slight convexity to the left. This line indicates the superior mesenteric artery on the surface.
- ***Inferior mesenteric artery:*** Point A is marked on the median plane 4 cm below the transpyloric plane. Point B is marked 4 cm below the umbilicus and 4 cm to the left of the median plane. The two points are joined by a curved line with a slight convexity to the left.
- ***Common iliac and external iliac arteries:*** Point A is marked 1 cm below and to the left of the umbilicus. This marks the bifurcation of the abdominal aorta. Point B is marked on the midinguinal point which is the midway between the anterior superior iliac spine and the pubic symphysis. The two points are connected by a broad line. The upper one-third of this line gives the surface marking of the common iliac artery, while its lower two-thirds give the marking of the external iliac artery.
- ***Right renal artery:*** Point A is marked 1.5 cm below the transpyloric plane on the midline. Point B is marked 4 cm lateral to point A on the right side. The two points are joined by a broad line. This indicates the right renal artery on the surface.

- ***Left renal artery:*** Point A is marked 1.5 cm below the transpyloric plane on the midline. Point B is marked 4 lateral to point A on the left side, but in such a way that the point lies 1 cm above the transpyloric plane. The two points are connected by broad line that runs upwards and to the left crossing the transpyloric plane.
- ***Inferior epigastric artery:*** Point A is marked midway between the anterior superior iliac spine and pubic symphysis. Point B is marked about 2 cm outer to umbilicus. The two points are joined by a line that runs upwards and medially and marks the outer boundary of the triangle of Hesselbach.
- ***Inferior vena cava:*** Point A is marked just below the transtubercular plane, 2.5 cm to the right of the median plane. Point B is marked on the sternal end of the right sixth costal cartilage. To indicate the inferior vena cava on the surface two parallel lines which are 2.5 cm apart are drawn connecting the two points.
- ***Common and external iliac veins:*** Point A is marked just below the transtubercular plane about 2.5 cm to the right of the midline (indicating the lower end of inferior vena cava). Point B is marked on the inguinal ligament a little medial to the midinguinal point. The two points are connected by a broad curved line that has a convexity laterally. The upper one-third of this line represents the common iliac vein, while its lower two-thirds represent the external iliac vein.
- ***Portal vein:*** Point A is marked on the transpyloric plane a little to the right of the midline. Point B is marked about 1 cm to the right of point A. Two parallel lines are drawn from these two points; they run upwards and to the right for a distance of about 5 cm. These two lines mark the right and left margins of the portal vein.

PARTS OF DIGESTIVE TRACT

Stomach

The outline of the stomach can be marked on the surface (Fig. 17.3) by first defining the cardiac and pyloric ends and then drawing the lesser and greater curvatures by joining these ends with curved lines.

- The ***cardiac end*** of the stomach lies over the left 7th costal cartilage.
  - Point A is marked on this costal cartilage 2.5 cm to the left of the midline. This point marks the middle of the cardiac orifice.
  - Point B is marked 1 cm to the right of this point and point C is marked 1 cm to the left of it.
- The ***pyloric orifice*** is also about 2 cm broad and lies on the transpyloric plane.
  - Point D is marked on the transpyloric plane about 1.2 cm (half an inch) to the right of the midline. This point indicates the middle of the pyloric orifice.
  - Point E is marked 1 cm to the right of this point, and Point F is marked 1 cm to the left of it.
  - Point B and point E are joined by a curved line which is concave upwards. The lowest part of this curve reaches slightly below the transpyloric plane. This 'J' shaped line marks the ***lesser curvature*** on the surface.
  - Point C and point F are joined by a much longer line representing the ***greater curvature***. The first part of the line is drawn with an upward convexity that reaches the fifth left intercostal space just below the nipple. It then continues to the left and downwards to return to the level of point A. The line upto this point represents the outline of the fundus of the stomach. The second part of the line forms a convexity to the left and downwards, cutting the costal margin between the tips of the 9th and 10th costal cartilages, and extending down to the level of the subcostal plane. This part marks the margin of the body of the stomach.

It should be remembered that the outline of the stomach as marked above is only approximate, as it changes with distension and respiration.

Duodenum (Fig. 17.7)

- ***First part of duodenum:*** Point A is marked on the transpyloric plane,1.2 cm to the right of the midline. Point B is marked 2.5 cm above and 2.5 cm to the right of point A. These two points are joined by two parallel lines about 2.5 cm apart; the broad marking represents the first part of duodenum on the surface.
- ***Second part of duodenum:*** It is continuous with the termination of the first part. Point C is marked 7.5 cm vertically below point B, medial to the right lateral plane. Two parallel lines about 2.5 cm apart are drawn joining points B and C; the broad marking thus made out represents the second part of duodenum on the surface. The right margin of this part of duodenum lies along the right lateral line and the lower end reaches the subcostal plane.
- ***Third part of duodenum:*** It lies transversely at the level of the subcostal plane. Point D is marked on the median plane, 10 cm to the right of point B. Points C and D are joined by two parallel lines about 2.5 cm apart; the wide marking made out should be curved with a slight convexity downwards. These lines represent the third part of duodenum on the surface. The third part of duodenum crosses the median plane, lying above the level of the umbilicus.
- ***Fourth part of duodenum:*** Point E is marked 2.5 cm to the left of midline and 1 cm below the transpyloric plane (Fig. 17.7). Two parallel lines 2.5 cm long and 2.5 cm wide are drawn to join the points D and E mark the fourth part of duodenum on the surface.

Root of Mesentery

Point A is marked 2.5 cm to the left of the midline and 1 cm below the transpyloric plane (This point corresponds to the position of the ***duodenojejunal junction***). Point B is marked at the junction of the right lateral and intertubercular planes. This point marks the position of the ***ileocaecal junction***. The root of mesentery can be represented by a broad obliquely placed line, about 15 cm long connecting points A and B (Fig. 17.9).

Caecum and Appendix

Point A is marked at the intersection of the right lateral and intertubercular planes. This indicates the ileocaecal junction. A vertical line about 6 cm long is drawn from point A downwards. This line marks the left margin of caecum. Another vertical line is drawn parallel to the first line and 7.5 cm to its right. This line marks the right margin of caecum. A curved line drawn to join the lower ends of the two lines completes the outline of caecum.

The ***root of the appendix*** is marked by a point 2 cm below the ileocaecal orifice.

There is not much reason in trying to mark the root of appendix on the surface because of the great variability that occurs in the position of the appendix. It is worth to remember that the average length of the appendix is 9 cm, but it can be much shorter or longer.

Large Intestine (Fig. 17.10)

- ***Ascending colon:*** Point A is marked on the transtubercular plane just lateral to the right lateral plane. Point B is marked 10 cm to the right of midline and 2.5 cm below the transpyloric plane. This point marks the right colic flexure. Two parallel lines which are 5 cm apart drawn connecting the above points mark the ascending colon on the surface.
- ***Transverse colon:*** Point A is marked 10 cm to the right of the midline and 2 cm below the transpyloric plane (indicating the right colic flexure). Point B is marked 5 cm medial to point A. Point C is marked on the umbilicus. Point D is marked 10 cm to the left of the midline and 2 cm above the transpyloric plane. The transverse colon is marked by two parallel lines which are 5cm apart drawn to connect these points.
- ***Descending colon:*** Point A is marked 10 cm to the left of midline and 2 cm above the transpyloric plane (indicating the left colic flexure). Point B is marked on the fold of groin, lateral to the left lateral plane and just above the inguinal ligament. The two points connected by a line which is about 2.5 cm broad.
- ***Sigmoid colon:*** The sigmoid colon is in the form of a coil that lies predominantly in the true pelvis. No useful purpose is served by trying to mark it on the surface. It begins, as a continuation of the descending colon, just above the left inguinal ligament and descends into the true pelvis. It terminates near the midline of the pelvis by becoming continuous with the upper end of the rectum.
- ***Rectum and anal canal:*** Points A and B are marked on the posterior superior iliac spines on either side. Point C is marked just below the second sacral spine. Point D is marked just below the tip of coccyx (indicating the anorectal junction). Points A and B are connected to the points C and D. The whole stretch indicates the rectum on the lower part of the back.

Biliary Apparatus, Pancreas and Spleen

- ***Liver:*** The projection of the liver can be drawn both on the anterior and posterior aspects of the trunk. When seen from the front or from the back, the liver has a triangular outline. The triangle is bounded by superior, inferior and right lateral borders.
  - ***Superior border:*** Point A is marked on the left fifth intercostal space, 9 cm from the midline, just below the nipple. Point B is marked on the xiphisternal joint. Point C is marked on the junction of right fifth costal cartilage and the right lateral line. Point D is marked over the sixth rib on the midaxillary line. Point E is marked on the inferior angle of right scapula. Point F is marked on the midline (at the back) at the level of eighth thoracic spine. The above points are connected in serial by straight lines except the line connecting points B and C has a slight convexity upwards. The whole stretch represents the superior border of liver on both anterior and posterior surfaces of the trunk.
  - ***Inferior border:*** Point G is marked over the tip of the left eighth costal cartilage. Point H is marked at the intersection of the transpyloric plane with the midline. Point I is marked over the tip of the ninth costal cartilage along the costal margin. Point J is marked over the tip of the tenth costal cartilage on the midaxiillary line. Point K is marked on the midline (at the back) at the level of the eleventh thoracic spine. A line is drawn connecting point A (starting point of the upper border) with points G,H,I,J and K. This line indicates the inferior border of the liver.
  - ***Right border:*** Point L is marked 1 cm below the tip of the right tenth costal cartilage. The right border is represented by a line joining points C and L. This line is curved with a slight convexity to the right.
- ***Fundus of gallbladder:*** Fundus of the gallbladder is marked as a small convex area just below the lower border of liver, over the place where the right linea semilunaris meets the costal margin.
- ***Bile duct:*** The projection of the second part of the duodenum is drawn as described in the concerned passage. Point A is marked 5 cm above the transpyloric plane and 2 cm to the right of the midline. Point B is

marked on the medial border of the second part of duodenum at about its middle. The two points are connected by a line which at first runs vertically downwards for 4 cm and then inclines to the right. This line represents the bile duct on the surface.

- ***Pancreas:*** The projection of the second part of duodenum is drawn. The inner border of the C-shaped curve of the duodenum demarcates the head of the pancreas. Two lines, which are about 3 cm apart and which pass slightly upwards and to the left from the head are drawn. The initial 1 cm of these lines lies over the transpyloric plane. This part represents the neck of pancreas (which lies behind the pylorus). The two lines are continued upwards and to the left till they reach the subcostal plane. This continuation of the lines for about 10 cm in length represents the body of pancreas. The terminal part of the same lines represents the tail.
- ***Spleen:*** Point A is marked over the right 10th rib, about 5 cm from the midline on the back. This marks the medial end of the spleen. Point B is marked over the right 10th rib in the midaxillary line on the back. This marks the lateral end of the spleen. The two points are joined by a line that is convex upwards so that its uppermost part reaches the upper border of the right 9th rib. This line marks the upper border of the spleen. The same two points are joined by a line that is convex downwards and that reaches the lower border of the right 11th rib. This marks the lower border of the spleen.

PARTS OF URINARY TRACT

Kidneys

Kidneys can be marked both on the anterior and posterior surfaces of the trunk.

Surface Marking from the Front

- ***Right kidney:*** Point A is marked a little below the transpyloric plane, 5 cm lateral (right side) to the midline, a little medial to the tip of the ninth costal cartilage (this marks the hilum). Point B is marked 2.5 cm below this point. Point C is marked 4 cm above point A and 2.5 cm from the midline. Point D is marked 4 cm below point B and 7.5 cm from the midline. Point E is marked on the transpyloric plane 4 cm lateral to point A (Fig. 20.3).
  - Point A is connected to point B by a line that is curved with a medial concavity. Point A is connected to point C and point B is connected to point D by lines which are curved with medial convexities. The outline for the kidney is completed by connecting points C and D with a line that is curved with a lateral convexity and passing through point E.
- ***Left kidney:*** Point A is marked a little above the transpyloric plane, 5 cm lateral (left side) to the midline, a little medial to the tip of the ninth costal cartilage (this marks the hilum). Point B is marked 2.5 cm above this point. Point C is marked 4 cm above point A and 2.5 cm from the midine. Point D is marked 4 cm below point A and 7.5 cm from the midline. Point E is marked on the transpyloric plane 4 cm lateral to point A.
  - Point A is connected to point B by a line that is curved with medial concavity. Point B is connected to the point C and point A is connected to point D by lines which are curved with medial convexities. The outline for the kidney is completed by connecting points C and D with a line that is curved with a lateral convexity and passing through point E.

Surface Marking from Behind (Fig. 20.12)

The area in which the kidney lies can be represented as a parallelogram (***Morris parallelogram***).The superior and inferior boundaries of this parallelogram are formed by transverse lines drawn through the eleventh thoracic and third lumbar spines. Its medial and lateral boundaries are formed by vertical lines drawn 2.5 cm and 9 cm from the midline (Fig. 20.12).

The outline of the kidney can be drawn within the parallelogram such that the vertical diameter of the kidney is about 11 cm and the transverse diameter is about 6 cm. The right kidney is drawn slightly lower than the left kidney. The hilum of the kidney lies at the level of the first lumbar spine .The superior pole lies at the level of the 11th thoracic spine. The inferior pole lies at the level of the third lumbar spine.

Suprarenal Glands

The outline of the kidneys are drawn as explained above. A triangle that is 3 cm long and 3 cm wide is drawn above the upper pole of the right kidney; this triangle represents the right suprarenal gland. A semilune that is 4.5 cm long and 2 cm wide is drawn close to the medial border of the left kidney above the hilum. This marks the left suprarenal gland.

Ureter (Abdominal Part)

Like the marking of the kidney, the abdominal part of the ureter can also be marked from the front or from the back.

- ***Ureter marked on the front:*** Point A is marked at the tip of the 9th costal cartilage. Point B is marked on the pubic tubercle. A line joining these two points marks the position of the abdominal part of the ureter.
- ***Ureter marked on the back:*** Point A is marked 4 cm lateral to the second lumbar spine. Point B is marked on the posterior superior iliac spine. A line joining these two points marks the position of the abdominal part of the ureter on the back.

Added Information

Some Clinically Important Landmark Points

- ***Capuron's points:*** The two iliopubic eminences and the two sacroiliac joints—the four fixed points of pelvic inlet.
- ***Clado's points:*** A point at the junction of the interspinous line and the linea semilunare; in appendicitis, tenderness occurs here.
- ***Lian's point:*** A point at the junction of the lateral one-third and middle one-third of a line passing from umbilicus to anterior superior iliac spine; the needle or trocar for abdominal paracentesis can be safely introduced here.
- ***Mayo-Robson's point:*** A point just above and to the right of the umbilicus; this is the point where tenderness occurs in pancreatic diseases.
- ***Munro's point:*** A point (variable) along the right linea semilunare from the umbilicus to groin where tenderness is felt in appendicitis.
- ***Voillemier's point:*** A point on the linea alba, 6 cm below the line connecting the two anterior superior iliac spines; this is where a distended bladder can be safely punctured.

Multiple Choice Questions

1. Plain X-ray abdomen is commonly taken in which view?
 a. Antero posterior view
 b. Postero anterior view
 c. Lateral view
 d. Oblique view

2. All are true about descending pyelogram except:
 a. Dye is injected intravenously
 b. Catheter in urethra can be seen
 c. Both sides can be visualized simultaneously
 d. Contrast medium becomes visible in X-rays almost immediately after injection

3. Addison's superior clinical plane corresponds to:
 a. transtubercular plane
 b. Subcostal plane
 c. Transpyloric plane
 d. Supracristal plane

4. Duodenal cap is a normal finding in:
 a. Cholecystography
 b. Barium meal
 c. Pyelography
 d. Barium enema

5. Superficial inguinal ring is marked on the surface:
 a. 1 cm above and 1cm lateral to pubic tubercle
 b. 1 cm above and 1cm medial to pubic tubercle
 c. 1 cm below and 1 cm lateral to pubic tubercle
 d. 1 cm below and 1 cm medial to pubic tubercle

ANSWERS

1. a 2. b 3. c 4. b 5. a

Clinical Problem-solving

Case Study 1: A 57-year-old woman undergoes intravenous pyelography. It is noticed that there is no proper flow in her right ureter. The same ureter also shows dilatation. The renal pelvis and calyces also show dilatation on the right side.

- What do you suspect in this woman?
- What do you call the conditions of ureteric dilatation and calyceal dilatation?
- What other contrast radiography is related to the same system?

Case Study 2: A 32-year-old woman has had a hysterosalpingography. Her peritoneal cavity on the right side shows the contrast material.

- What structures are visualized in this radiograph?
- What does the fact that dye has spilled into the peritoneal cavity indicate?
- What anatomical feature is responsible for this spilling?

(For solutions see Appendix).

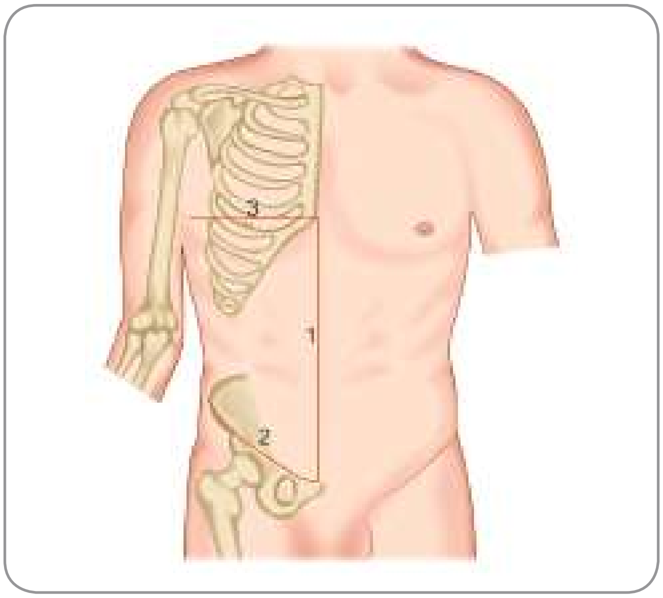
Appendix

DISSECTIONS

INCISIONS FOR ABDOMINAL REGION

Skin Incisions usually made for dissection of the abdominal region:

1. A vertical incision from the xiphoid process to the pubic symphysis.
2. An oblique and curved incision from the pubic symphysis to the anterior superior iliac spine along the inguinal ligament.
3. A transverse incision that runs straight from the xiphoid process to the lateral aspect of the trunk.
   The umbilicus is usually preserved by making incision 1 go around it



SOME FREQUENTLY USED TERMS AND THEIR PLURAL FORMS

Singular	Plural
Thorax	Thoraces (pronounced thoraseez)
Sternum	Sterna
Costa	Costae
Vertebra	Vertebrae
Mediastinum	Mediastina
Corpus	Corpora
Trachea	Tracheae
Bronchus	Bronchi
Oesophagus	Oesophagi
Pleura	Pleurae
Atrium	Atria
Ventricle	Ventricles
Septum	Septa
Hilum	Hila
Aorta	Aortae
Abdomen	Abdomina
Region (English)	Regions
Regio (Latin)	Regiones (pronounced regioneez)
Appendix	Appendices
Duodenum	Duodena
Pancreas	Pancreata
Jejunum	Jejuna
Ileum	Ilea
Rectum	Recta
Anus	Anus (not ani, which is a generic term)
Vesica	Vesicae
Urethra	Urethrae
Uterus	Uteri
Diaphragm/Diaphragma	Diaphragmata
Ulcer/Ulcus	Ulcers (commonly used English form)/Ulcera (rarely used Latinised form)
Umbilicus	Umbilici
Cervix	Cervices (pronounced cervicees)
Viscus	Viscera
Vas rectum	Vasa recta
Duct/Ductus	Ducts/Ductus
Testis	Testes
Epididymis	Epididymides
Scrotum	Scrotums (colloquially used)/Scrota
Pelvis	Pelves
Perineum	Perinea
Sacrum	Sacra
Ilium	Ilia

contd…

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Ischium	Ischia
Pubis	Pubes
Labium	Labia
Labium majus	Labia majora
Labium minus	Labia minora
Penis	Penises
External intercostal/Intercostalis externus (muscle)	External intercostals/Intercostales externi
Internal intercostal/Intercostalis internus (muscle)	Internal intercostals/Intercostales interni
Innermost intercostal/Intercostalis intimus (muscle)	Innermost intercostals/Intercostales intimi
Pubococcygeus	Pubococcygei
Puboprostaticus	Puboprostatici
Puborectalis	Puborectalii
Quadratus lumborum	Quadrati lumborum
Rectus abdominis	Recti abdominales
Transversus abdominis	Transversi abdominales
Transversus thoracis	Transversi thoraces
Omentum	Omenta
Hernia	Herniae
Fossa	Fossae
Foramen	Foramina
Fovea	Foveae
Ligament/Ligamentum	Ligaments/Ligamenta
Linea	Lineae
Plexus	Plexuses (English)/Plexus (Latinised)
Ganglion	Ganglia
Region (English)	Regions
Regio (Latinised usage)	Regiones (pronounced regioneez)
Lamina	Laminae
Spleen	Splenula
Corpus	Corpora
Crus	Crura
Radix	Radices (pronounced radiceez)
Artery/Arteria	Arteries/Arteriae
Vein/Vena	Veins/Venae
Sinus	Sinuses (English version)/Sinus (Latinised)
Calculus	Calculi
Calyx/Calyx	Calyces/Calices
Canal/Canalis	Canals/Canales
Node/Nodus	Nodes/Nodi
Trigonum	Trigona
Hepar/Heparis	Heparia
Lobe/Lobus	Lobes/Lobi
Lobule/Lobulus	Lobules/Lobuli

LIST OF ALTERNATE NAMES

Poupart's ligament/Vesalius ligament/Femoral arch	Inguinal ligament
Gimbernat's ligament	Lacunar ligament
Haller's arches	Medial and lateral arcuate ligaments
Ligamentum latum pulmonis	Pulmonary ligament
Ligamentum latum uteri	Broad ligament of uterus
Lannelongue's ligaments	Sternopericardial ligaments
Infundibulopelvic ligament	Suspensory ligament of ovary
Ligamentum teres uteri	Round ligament of uterus
Krause's ligament	Transverse perineal ligament
Ischioanal fossa/Velpeau's fossa	Ischiorectal fossa
Waldeyer's fossae	Duodenal recesses
Corpus candicans	Corpus albicans
Glomus coccygeum/Arteriococcygeal gland/Gland of Luschka	Corpus coccygeum
Corpus highmori	Mediastinum testis
Organs of Zuckerkendl/Zuckerkendl bodies	Para aortic bodies
Scapus penis	Body of penis
Botallo's foramen	Orifice between the two atria in foetal heart
Duverney's foramen	Foramen epiploicum/Foramen of Winslow
Foramen subseptale	Ostuim primum (of interatrial septum)
Lannelongue's foramina/Vieussens' foramina	Openings of venae minimae into right atrium/Thebesian foramina
Morgagni's foramen	Defect in the fusion of the sternal and costal elements of diaphragm
Foramen quadratum	Vena caval opening of the diaphragm
Pelvic sacral foramina	Anterior sacral foramina
Dorsal sacral foramina	Posterior sacral foramina
Botallo's duct	Ductus arteriosus
Common gall duct/Gall duct	Common bile duct/Bile duct
Testicular duct	Ductus deferens
Bernard's duct/Santorini's canal	Accessory pancreatic duct
Hoffman's duct/Wirsung's canal	Main pancreatic duct
Muller's duct	Paramesonephric duct
Leydig's duct/Wolffian duct	Mesonephric duct
Hepatocystic duct	Common hepatic duct
Gartner's duct or canal/Malpighian duct	Longitudinal duct of epoophoron
Van Hoorne's canal/Pecquet's duct	Thoracic duct
Arantius' duct or canal, ductus venosus Arantii	Ductus venosus
Douglas line	Arcuate line of pelvis
Hilton's line	White line of anal canal
Hunter's line	Linea alba
Lanz's line	Interspinous line (connecting the two ASI spines)
Kilian's line	Transverse line of sacral promontory
Mamillary line/Nipple line	Midclavicular line
Monro-Richter line	Line connecting umbilicus to left ASIS
Poupart's line	Line through the centre of inguinal ligament

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Line of Spigelius	Linea semilunaris (of anterior abdominal wall)
Sternal line	Midline of sternum
Winslow's pancreas/Willis's pancreas/Lesser pancreas	Uncinate process of pancreas
Jonnesco's fossa/Duodenojejunal fossa	Superior duodenal recess (of peritoneum)
Gruber's fossa	Inferior duodenal recess (of peritoneum)
Inferior omental recess	Part of lesser sac extending between the 2nd and 3rd layers of greater omentum
Claudius fossa	Ovarian fossa
Spigelian lobe	Caudate lobe of liver
Scrobiculus cordis	Epigastric region of abdomen/epigastric fossa
Morgagni's fossa	Navicular fossa of urethra
Plexuses gulae	Oesophageal (nervous) plexuses
Left anterior descending artery (LAD)	Anterior interventricular branch of left coronary artery
Posterior descending artery (PD)	Posterior interventricular branch of right coronary artery
Acute marginal artery (AMA)	Right marginal branch of right coronary artery
Obtuse marginal artery (OMA)	Left marginal branch of left coronary artery
Clado's band	Suspensory ligament of ovary with the peritoneum covering it
Reil's band	Septomarginal trabecula
Koch's node, Keith's node, Atrionector, Keith and Flack's node	Sinoatrial node (SA node)
Aschoff and Tawara's node	Atrioventricular node
Sinuses of Valsalva/Petit's sinuses	Aortic sinuses
Sinus pocularis	Prostatic utricle
Sinus reuniens	Sinus venosus
Krukenberg's veins	Central veins of liver
Mayo's vein/Latarjet's vein	Prepyloric vein
Marshall's vein	Oblique vein of left atrium
Retzius' veins/Ruysch's veins	Veins from intestines which join the inferior venacaval tributaries directly without going through the portal venous system
Vieussen's veins	Nameless small veins of the heart
Anterior coronary plexus/Plexus coronaria cordis	Part of the cardiac plexus found in close association with the coronary arteries on the anterior aspect of the heart
Thoracic aortic plexus	Part of the aortic (autonomic) plexus found extending into the thoracic cavity through the aortic opening
Solar plexus/Cerebrum abdominal/Abdominal brain/Vieussen's ganglion	Coeliac (autonomic) plexus
Enteric plexus	Collective term denoting the submucous and myenteric plexuses of the intestines
Pelvic plexus	Inferior hypogastric plexus
Presacral plexus	Superior hypogastric plexus
Remak's plexus	Meissner's plexus
Redux testis	A testis that shows tendency to ascend to the upper scrotum or to the inguinal canal
Lieutaud's trigone	Trigone of the urinary bladder
Larrey's cleft/Sternocostal triangle	Gap between the sterna and costal portions of the diaphragm
Inguinal triangle	Hesselbach's triangle

Solutions to Clinical Problems

SECTION 4 THORAX

CHAPTER 1

Case Study 1

- Yes. I agree.
- Backward curving of ribs gives a flat back.
- Anteroposterior flattening of the thoracic cavity, dorsal displacement of scapulae and the submergence of the vertebral spines into the gutter created by the backward curving of the ribs are the associated features.

Case Study 2

- Compression of the brachial plexus and the subclavian vessels at the thoracic outlet as they pass into the upper limbs.
- Boundaries of thoracic outlet are—***posteriorly***, body of first thoracic vertebra; ***laterally*** (on both sides), first ribs and first costal cartilages; ***anteriorly***, upper part of manubrium sterni.
- Restricted space, obliquity of the aperture, further restriction of space by an additional structure like cervical rib, hypertrophy of scalenus anterior muscle are some of the causes for a thoracic outlet syndrome to occur.

CHAPTER 2

Case Study 1

- The anatomical basis for disc prolapsed is that the annulus fibrosus is thinnest posteriorly and the nucleus pulposus can protrude through this portion. However, the prolapsed is actually made posterolateral by the posterior longitudinal ligament.
- The lumbar vertebral column suffers more compression than the other parts of the vertebral column. It has to bear the weight of the upper column and also withstand the compression forces produced by weights which are lifted by the individual through the upper parts of the body. So, herniation is more common here.

Case Study 2

- None. Lordosis is a normal phenomenon in pregnancy.
- Obesity and carrying heavy weights especially with force from the upper part of the body are the usual causes for temporary lordosis.

CHAPTER 3

Case Study 1

- The condition is ectopia cordis.
- The sternum and the adjoining parts of ribs and costal cartilages are missing.
- A similar condition in the abdomen is exomphalos.

Case Study 2

- Cervical rib is a condition where there is an additional rib in the cervical region. The usual anomaly is that the C7 vertebra has a rib on one side or both sides.
- The presence of a cervical rib will cause mechanical disadvantages. The space of the thoracic outlet (superior thoracic aperture) would be narrowed. The brachial plexus and the subclavian vessels are likely to be compressed. The lower part of brachial plexus or the suclavian vessels may have to take a curved course (go up and then come down over the rib) which can lead to compression or kinking.

- When the brachial plexus is postfixed, the normal first rib can behave like a cervical rib causing similar problems.

CHAPTER 4

Case Study 1

- The term indicates that the nucleus pulposus portion of the intervertebral disc has prolapsed through the annulus fibrosus. Such prolapse occurs usually on the posterior aspect.
- Compression forces on the intervertebral discs added to age changes (annulus fibrosus becoming weak) which reduce the pliability of the intervertebral discs predispose to this condition.
- Compression of spinal nerves produce symptoms related to the compression. The level of compression depends on the level of the disc prolapse. Usually lumbar disc is more prone to prolapse and so compression of the sciatic nerve occurs.

Case Study 2

- Yes. It can be considered a normal finding.
- This change is seen after the age of 30.
- The manubriosternal joint is a symphysis.

CHAPTER 5

Case Study 1

- The 6th intercostal space in the midaxillary line will be my choice of location.
- In a particular space, the needle should be passed through the lower part of the space to avoid injury to the neurovascular bundle.
- The needle will pass through (penetrate through) (from outside inwards) skin, superficial fascia, serratus anterior muscle, all three layers of intercostals muscles and parietal pleura.

Case Study 2

- A rolling hiatus hernia is also called a ***paraoesophageal hernia***. A part of the stomach passes through the oesophageal hiatus of the diaphragm into the thorax and lies within the posterior mediastinum parallel to the oesophagus.
- The hiatus is at fault, probably being larger than normal.
- There is no reflux because the cardio-oesophageal junction is normal.

CHAPTER 6

Case Study 1

- Pleuritis (also called pleurisy) is the probable diagnosis.
- The patient has had neck pain probably because the diaphragmatic or the mediastinal pleurae were affected. Due to a common nerve supply by the phrenic nerves, neck pain should have resulted.
- Friction rub is the rubbing of pleural layers heard during auscultation. Due to pleuritis, the visceral and parietal layers of pleura thicken and become rough. They rub against each other during respiratory movements.

Case Study 2

- It does. It suggests a diagnosis of emphysema.
- In this condition, large spaces are found in the lung parenchyma and there is considerable dilatation of alveoli. The anatomical reason is that there is prolonged respiratory obstruction which causes the alveoli to dilate.
- As stated earlier, the condition is called emphysema.

CHAPTER 7

Case Study 1

- Angina pectoris is a condition where the individual experiences constricting pain in the chest. It is caused by a temporary deficiency in the delivery of blood to the myocardium.
- Pain is predominantly in the region of sternum (substernal pain). It can radiate to left shoulder,left arm, neck, jaw and to the back, mainly on the left side.
- Angina indicates temporary block in the blood supply. When the blood supply is completely interrupted, mayocardial infarction is caused.

Case Study 2

- None of the valves are directly heard.
- The aortic valve is best heard at the right superior corner and the pulmonary valve at the left superior corner.
- The heart sounds reach the chest wall by traversing through the chambers in oblique routes.

CHAPTER 8

Case Study 1

- He is suffering from coarctation of aorta.
- There is hypertension in areas supplied by branches arising proximal to the constriction and hypotension in areas supplied by branches arising distal to the constriction. Yes. He will have radiofemoral delay.
- Blood flows into the intercostal arteries from the internal thoracic artery and flows back towards the aorta. This causes rib notching.

Case Study 2

- He has problem with his coronary arterial supply.

- It is bypassing the blocked coronary vessel with another graft vessel. It is a shortened form of coronary artery bypass grafting.
- Angioplastic stenting (percutaneous transluminal coronary angioplasty) can be tried.

CHAPTER 9

Case Study 1

- There are no lymphatics near the alveoli. If there were to be lymphatics close to alveoli, air may be sucked into the lymph vessels and thence move into the blood stream resulting in air embolism.

CHAPTER 10

Case Study 1

- Diaphragm.
- Due to common or shared origin as far as nerve supply is concerned.
- The phenomenon is called ***referred pain***.

Case Study 2

- Vasospasm of upper limb occurs.
- The sympathetic trunk is involved.
- Surgical resection of the sympathetic trunk below T3 ganglion.

CHAPTER 11

Case Study 1

- The procedure to be asked for is echocardiography.
- The higher variant is Doppler echocardiography.

Case Study 2

- The points to be noted are—the lung fields and hilar markings, the ribs and costal cartilages, the heart shadow and its boundaries, aorta and other vessels and the domes of diaphragm. Abnormalities in structure, position and orientation should be looked for.

SECTION 5 ABDOMEN AND PELVIS

CHAPTER 12

Case Study 1

- The question is a relevant.
- The position of some viscera can change according to the sitting or standing position of the individual.
- The position of the viscera can be properly assessed on knowing the position at which the radiograph was taken.

CHAPTER 13

Case Study 1

- The dimensions of the true pelvis of the mother should be able to permit the head of the foetus to pass through. When the dimensions are small enough that the foetal head cannot pass through, the condition is called ***cephalopelvic disproportion***.
- The condition is diagnosed and confirmed by assessing the dimensions of the pelvis. This assessment is called ***pelvimetry***.
- Delivery of the foetus will be difficult and a caesarean section has to be resorted to.

CHAPTER 14

Case Study 1

- It is actually a paraumbilical hernia.
- The possible predisposing factors are obesity, weakened muscles of the abdominal wall (due to aging, accumulation of fat and reduced muscle tone) and repeated pregnancies.

Case Study 2

- The neck of the hernia is medial to the inferior epigastric vessels. The hernia does not pass through the deep inguinal ring but enters the inguinal canal by pushing through the posterior wall of the canal.
- Some other hernia are—indirect inguinal hernia, umbilical hernia, diaphragmatic hernia, femoral hernia.
- A hernia can be defined as a condition where the contents of a cavity protrude out of the cavity through a weakness of the wall of the cavity.
- However, a complete definition would be. ***A hernia is an abnormal protrusion of a viscus or structure of a cavity through a normal or abnormal orifice***.

CHAPTER 15

Case Study 1

- Bursting of an ischiorectal abscess would have been the primary cause for the ischiorectal sinus.
- Infections can track to the fossa from the anal canal, skin of perineum or rarely from a pelvirectal abscess. Infection from one ischiorectal fossa can travel to the fossa of the other side, posterior to the anal canal, resulting in a horseshoe abscess.
- The fat in the ischiorectal fossa is poorly vascularised; so, the fossa is vulnerable for infection.

Case Study 2

- The main reason in this patient is the weakening of the perineal body due to multiple pregnancies.

- The perineal body is the main structure responsible for the anatomical integrity of the perineum.
- The levator ani muscles and the pelvic diaphragm play a major role in holding the pelvic viscera in position. If they are weakened or lose their tone, prolapse is predisposed to.

CHAPTER 16

Case Study 1

- The part of peritoneum likely to be involved is the subdiaphragmatic peritoneum.
- The particular test that should be performed during clinical examination is the test of rebound tenderness.

Case Study 2

- Either the gallbladder or the vermiform appendix could have been primarily involved. Pus from any other organ of the region or from the lesser sac can also track to the Morison's pouch.
- The right posterior subphrenic space or the right sub-hepatic space is called the Morison's pouch. It is a space between the liver and the right kidney. The pouch of Douglas is a space that is the most dependent in the erect posture as is the ***Morison's pouch*** in the supine posture.

CHAPTER 17

Case Study 1

- The first diagnosis to be thought of in this condition is appendicitis.
- The pain of appendicitis and its location will be related to the position of appendix. Normally, it may cause pain in the right iliac fossa. A totally retrocaecal appendix causes pain in the hip joint, especially during extension. A pelvic appendix causes pain in the hypogastrium and also in the hip joint during flexion and internal rotation. A subhepatic appendix can simulate cholecystitis.
- McBurney's point is a point marked on the surface of the anterior abdominal wall at the junction of the lateral and middle thirds of a line joining the umbilicus and the right anterior superior iliac spine. This point indicates the base of the appendix. Surgeries for appendicitis are usually performed through a skin incision that is made at this point, but at right angles to the line.

Case Study 2

- The woman is likely to suffer from corrosions or ulcers of stomach or duodenum.
- Barium meal radiograph will help visualize the gastric or duodenal mucosa. Changes in the normal expected picture can be made out and analysed to diagnose the condition.

CHAPTER 18

Case Study 1

- The woman, is very likely, suffering from cholecystitis.
- Murphy's sign can be elicited in this condition. The examining finger should be placed at the meeting point of the right costal margin and the right linea semilunaris or at the tip of the right ninth costal cartilage. On asking to take a deep breath, the patient experiences a sharp pain.

Case Study 2

- This man is likely to be suffering from portal hypertension.
- The portal circulation is under jeopardy. So there is likely to be back stagnation of blood in the system, which in turn causes splenomegaly.

CHAPTER 19

Case Study 1

- The probable diagnosis is portal hypertension.
- The paraumbilical veins pass through the falciform ligament to reach the liver, where they anastomose with the left branch of the portal vein. In portal hypertension, blood flow is reversed and blood flows through these veins into the systemic circulation. Therefore, the superficial veins of the anterior abdominal wall enlarge and produce the appearance of caput medusa. The lower end of oesophagus is drained by veins some of which enter the portal circulation and others the systemic circulation. In portal hypertension, the communication between the two systems of veins opens up and results in their enlargement leading to oesophageal varices.
- Haemorrhoids and splenomegaly are the other expected features.

CHAPTER 20

Case Study 1

- The kidneys (especially the renal pelves) and the ureters are being tested.
- Pyelography can be descending or ascending. In descending pyelography, the contrast medium is intravenously injected and it is filtered from the blood into the renal tubules. Since the route involved is descending (from blood to kidneys), it is called so. In ascending pyelography, the contrast medium is sent into the urinary tract by entering into the urinary bladder. The contrast medium is made to ascend from the bladder to the ureters and renal pelves. Ascending pyelography is also called ***retrograde pyelography***.
- The ureter is likely to have been blocked.

Case Study 2

- The pain of ureteric colic starts at the loin and runs down to the groin.
- The ureter has three points of constriction. The presence of such constrictions facilitates calculi formation or predisposes to complications.

CHAPTER 21

Case Study 1

- Sacralisation means partial or complete fusion of the fifth lumbar vertebra to the sacrum.
- The opposite/complementary change is lumbarisation of sacrum, wherein, the first piece of sacrum becomes a separate vertebra.

Case Study 2

- The condition is called ***claudication***.
- The aorta is partially blocked by atheroma. Blood supply to lower limbs is reduced. When the patient attempts to walk, more blood is needed to the lower limbs. Contraction of muscles which do not get adequate blood supply leads to pain.

CHAPTER 23

Case Study 1

- The most probable diagnosis is haemorrhoids (or piles).
- The venous twigs of anal canal and the anorectal junction lie in loose submucous tissue. When the muscles contract during defaecation, these twigs which also pierce the muscle coat, are constricted and pressure inside them rises. The superior rectal and inferior mesenteric veins and their tributaries have no valves. So, the lower veins have to withstand the pressure of the entire column of blood from the anal canal to the portal veins. This leads to engorgement of veins and their dilatation.
- Predisposing factors include—(a) standing for long periods of time, (b) obesity (by increasing the intra-abdominal pressure), (c) any cause that leads to frequent and prolonged increase of intra-abdominal pressure, (d) Portal hypertension.

CHAPTER 24

Case Study 1

- Fibroid is a benign neoplasm – a fibroma – of the uterus. Usually, it is multiple.
- Caesarean section and hysterectomy are some surgical procedures done on the uterus.
- Hysterotomy is opening up of the uterus; hysterectomy is removal of the uterus.

Case Study 2

- It is a condition wherein the uterus descends into the vagina and part of it protrudes through the external orifice into the vestibule.
- Bulging of the urinary bladder into the vagina, through the weakened anterior wall of vagina, is called ***cystocoele***.
- Such a condition is called ***rectocoele***.

CHAPTER 26

Case Study 1

- This woman is likely to have ureteric obstruction.
- Ureteric dilatation is called ***hydroureter*** and calyceal dilatation is called ***hydronephros***.
- Ascending or retrograde pyelography is related to the urinary system.

Case Study 2

- The uterus and the uterine tubes are visualized in this procedure.
- The fact that the dye has spilled into the peritoneal cavity indicates that the woman's uterine tube (on the right side) is patent.
- The uterine tubes are normally open into the peritoneal cavity.

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